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VOLUME II

to

TECHNICAL REPORT SRC-71-TR-N3501

15 August 1971

ARCTIC OPERATIONS TECHNICAL NEEDS (U)

Appendix A
ARCTIC RESOURCES

by
A.G. Ronhovde
THE ARCTIC INSTITUTE OF NORTH AMERICA

prepared for
Director, Naval Analysis Programs
Naval Applications and Analysis Division
Office of Naval Research
Arlington, Virginia 22217

IN ACCORDANCE WITH CONTRACT NO. N00014-71-C-0305

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Advanced Research Projects Agency
ARPA Order No. 1769

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SYSTEMS RESEARCH CENTER
OF
WHEELER INDUSTRIES, INC.
1800 CONNECTICUT AVENUE, N.W.
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PREFACE

The following report on ARCTIC RESOURCES was prepared in accordance with the subcontract between the Systems Research Corporation and the Arctic Institute of North America dated May 6, 1971.

The starting point for the study was the Volume II, ARCTIC RESOURCES report dated 18 December 1970, by L.C. Van Allen, D. M. Tyree, and G.S. Sexton. Many sections of that report, including figures and tables, are incorporated in this study. After some investigation, it was concluded that in terms of potential economic and strategic importance, the major resources of the circumpolar arctic region were in the category of energy resources; more precisely, in oil and gas. In the light also of recent government and industry concern with the size and location of reserves of those fuels it was decided to place major emphasis on the oil and gas resources of the arctic region. In view of the evidence cited in the report, it is believed that the decision was warranted.

Acknowledgment is due to the authors of the December 1970 SRC report that much of the information therein on such subjects as population, industry, and transportation were reasonably up to date and no significant changes had occurred that would alter the overall picture.

The projections made for the 1970-2000 period are primarily related to the oil and gas development, because it was judged that they are the arctic resources that will be of greatest economic and strategic concern to the United States, and probably also to Canada and the U.S.S.R.

Andreas G. Ronhovde
June 05, 1971

Note:

The material in this report volume will be published in book form at a later date by the Arctic Institute of North America. Recipients of this report will receive copies of the book at that time.

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A.1 INTRODUCTION

Even for the circumpolar countries the arctic population is but a small fraction of their total population. The significance of arctic resources tends, therefore, to be considered mainly in terms of their meaning for peoples who themselves live outside the arctic, most of them far removed from that area. For this reason, a crucial question in the evaluation of the importance of arctic resources to the countries concerned, including the United States, is the feasibility of economic transportation of the resource to non-arctic markets. This, in turn, tends to focus attention on the arctic areas in which resources can be successfully exploited only by overcoming the special transportation problems associated with arctic conditions, such as ice, cold, permafrost, and other well known conditions. A resource that cannot economically be moved to population centers to the south is of little practical importance to the circumpolar countries. In view of the above factors this survey of arctic resources is mainly confined to the resources of the arctic regions that can be tapped only from ports, rail or road heads, landing fields, or collection points which are in the Arctic and must operate under arctic conditions. The sub-arctic, therefore, receives minor attention.

In a practical sense, arctic resources are important to the United States and other countries to the extent that they may help to satisfy an existing or potential demand. Aside from the potential demand for rare minerals or other critical substances that might be found in the Arctic,

it appears that major interest lies in the field of energy fuels. This situation results mainly from the anticipated heavy future demands of industrial society. The interest in the Arctic is whetted in turn by indications that the arctic region is, in fact, rich in precisely those resources. The resource survey, therefore, emphasizes energy fuels of the region, which means mainly its oil and gas resources.

A.2 U. S. ARCTIC RESOURCES

The U.S. arctic resources of interest to this survey are contained in the state and its continental shelf of Alaska, confined mainly to the areas in and north of the Brooks Range (Figure 1). The Kobuk River basin and parts of the Yukon River basin north of the Kuskokwim Mountains are of lesser concern. Within the regions mentioned, movements of resources must be through ice covered waters or through permafrost areas to a meaningful extent, and naval protection of the sources, storage, and transportation of the resources would have to mean operations in ice covered waters.

A.2.1 Energy Resources

A.2.1.1 Hydroelectric Power

The hydroelectric power-generation capacity for all of Alaska was only 84 thousand kilowatts in 1967. (1) However, for the whole of Alaska, the estimated water power potential is 32,511 thousand kilowatts, the greatest of any state. (1) Most of the potential is in the Kuskokwim and Yukon river basins. The water power potential of the northern region of the state, by comparison, is quite small. The readily available coal, gas, and oil energy sources make fossil fuel power plants competitive with hydroelectric

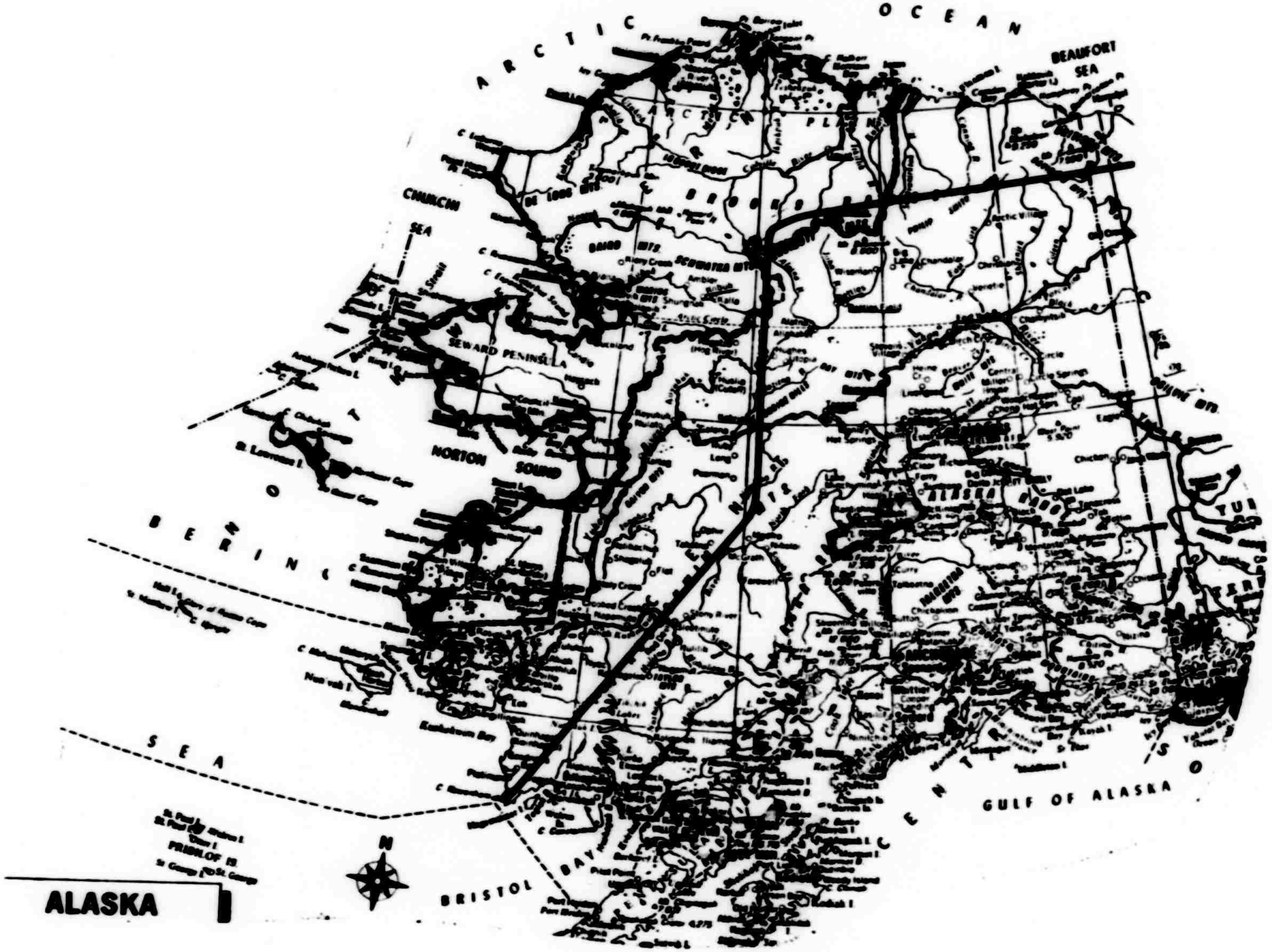


FIGURE 1 ARCTIC ALASKA

plants. The small population and limited industries in Alaska will also limit the development of hydroelectric power in the future, particularly in the northwest region.

A.2.1.2 Coal

Coal is widely distributed throughout many parts of Alaska (See Figure 2). The deposits range from extensive coal fields to isolated small occurrences. The principal coal fields are in five major regions: the northern Alaska region along the north slope of the Brooks Range; the central Alaska region, including Nenana coal field on the north flank of the Alaska Range; scattered occurrences on the Seward Peninsula, and the same in the Yukon and Kobuk River basins; the Cook Inlet - Susitna region; the Alaska Peninsula region; and the southeastern Alaska region. The last three are not, properly, in the arctic regions of the state. Total production in Alaska to the end of 1963 was about 14.6 million tons, mainly sub-bituminous coal from the Nenana field in central Alaska for the Fairbanks area, and 5.6 million tons of bituminous production in the Matanuska field in the Anchorage area. Very little coal has been produced elsewhere in Alaska. The total Alaska production, however, which was running 800-900 thousand tons annually after 1953, has increased to a total of 4.36 million tons in 1969. (2)

Coal-bearing rocks are known or inferred to underlie most of the part of Alaska which extends northward from the northern foothills of the Brooks Range to the Arctic Coast, and eastward from Cape Lisburne at least as far as the Itkillik and lower Colville rivers. The area of known

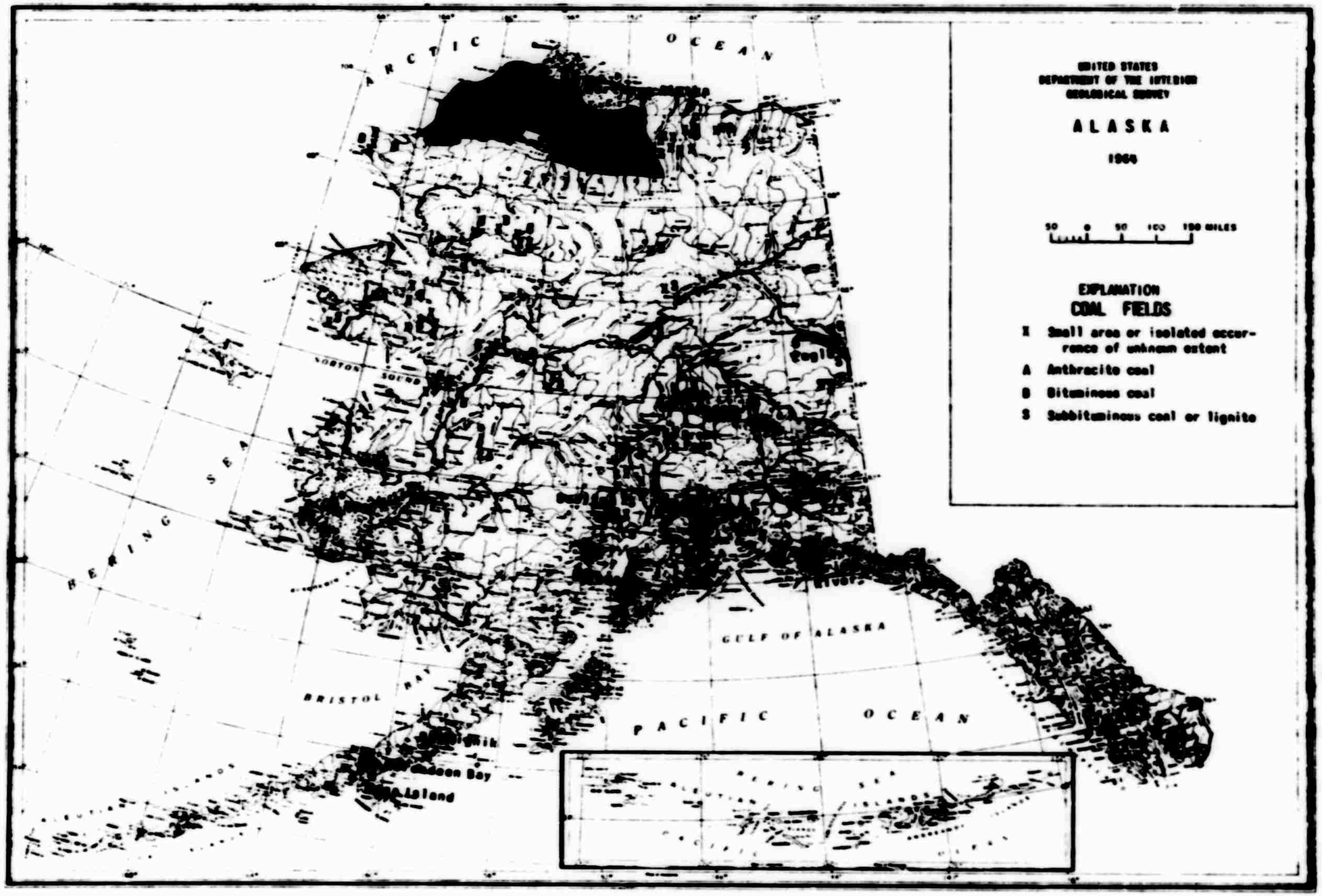


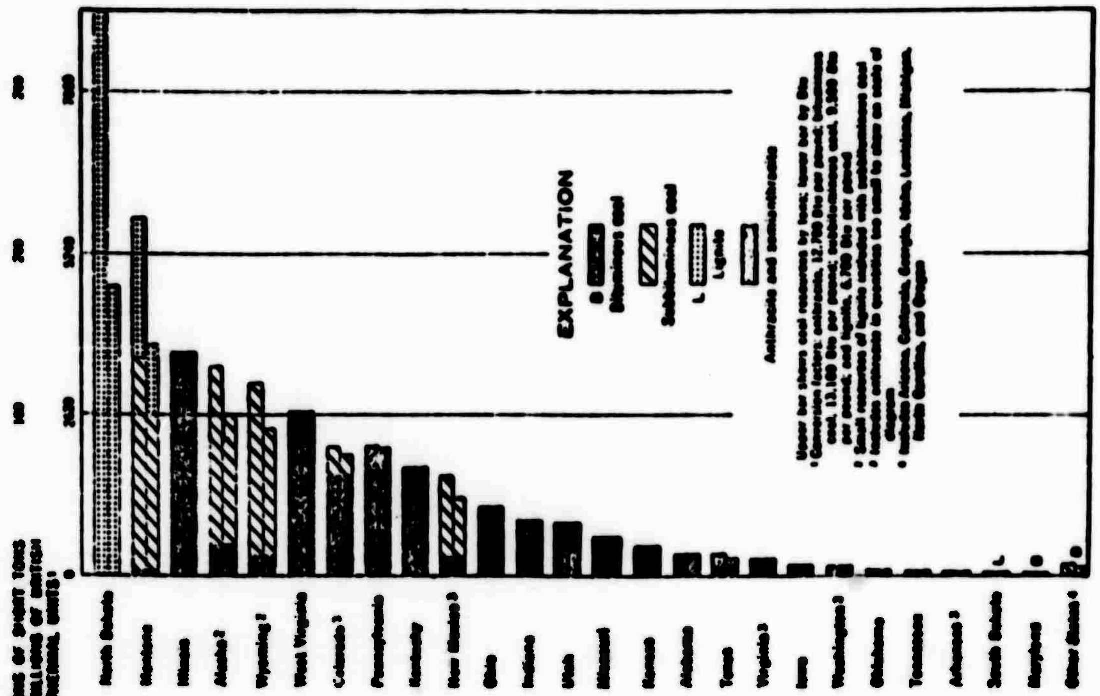
FIGURE 2 COAL FIELDS OF ALASKA

and potential coal-bearing land is about 58,000 square miles. Estimated coal resources for the region are estimated as high as 120,197 million tons, of which 19,292 million tons, are bituminous and 100,905 million tons sub-bituminous [3] The U.S. Bureau of Mines has reported that northwestern Alaska has "immense coal resources, as yet only sketchily outlined" in the area between Point Hope and Point Barrow, north of Bering Strait on the Chukchi Sea. [4] The coals are believed to be capable of producing metallurgical quality coke by blending with as little as fifteen percent of strongly coking coals. [4] The estimated coal reserves of the remainder of Alaska, mainly sub-bituminous coal and lignite, were estimated by the Geological Survey in 1964 at 10,000 million tons [5] but in 1969 the Bureau of Mines mentioned 15-20 million tons in the Bering River (Gulf of Alaska) area alone. [4]

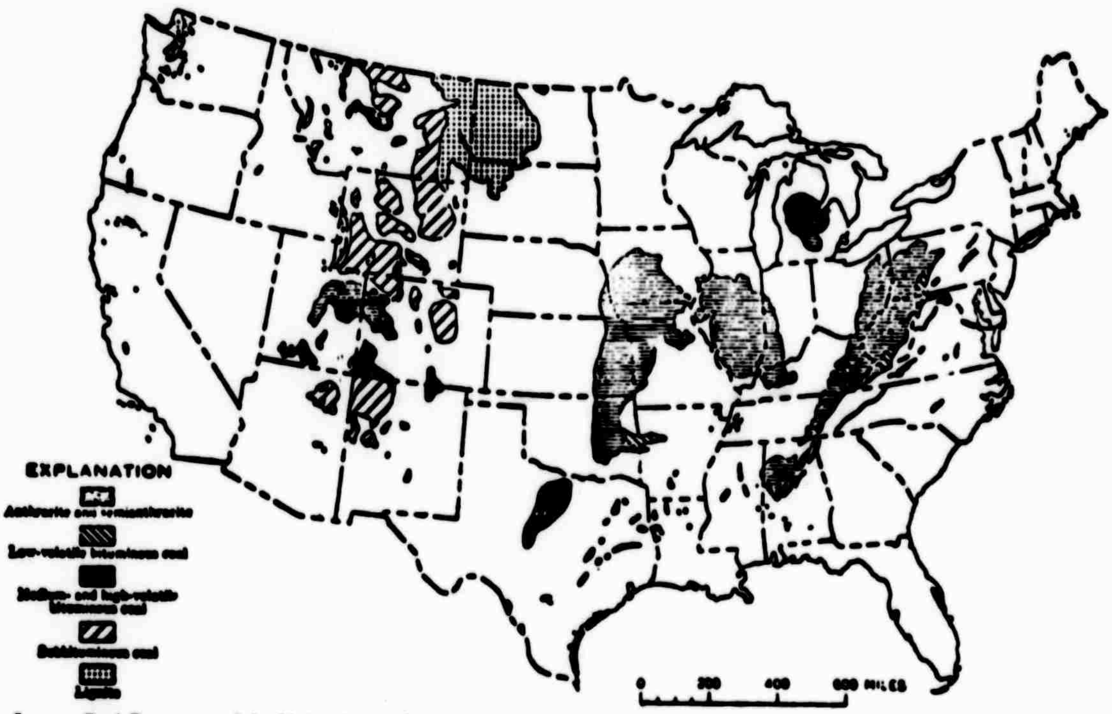
The total U.S. coal resources as shown in Figure 3 are estimated at 3,210 billion tons, of which half may be recoverable [1] Total U.S. coal production in 1968 was 556 million tons, about the same as in 1950. [1] A recent estimate of the Department of the Interior of 220 billion tons of U.S. mineable coal at or below present cost levels works out to cover 400 years supply at present rates of production, and is more than 100 times present annual production of energy from all sources. [1] The coal resources of Alaska rank fourth - behind North Dakota, Montana and Illinois. [6]

About half of the U.S. coal production is used to generate about half the U.S. electricity supply. It has been estimated that by the year 2000 coal

Remaining coal resources of the United States as determined by mapping and exploration, January 1, 1967, by States, according to tonnage and heat value



Source: "Coal Resources of the United States, January 1, 1967", op. cit., page 20.



Source: Coal Resources of the United States, January 1, 1967, op. cit., p. 5.

FIGURE 3 COAL RESOURCES

will furnish only about 30 percent of power for generation of electricity.[1] However, that estimate is based partly on a substantial increase in nuclear powered generators, a somewhat shaky assumption. The future of the coal mining industry in Alaska is dependent on a number of factors, including the growth of industry and population in Alaska and the U.S. and world demand.[7] Involved in this picture, obviously, will be the competitive position of Alaska coal in terms of relative cost. Coal shipments from Alaska to the lower 48 may well be unlikely. Foreign markets in countries, such as Japan, may have greater promise. The fact that some U.S. companies, such as Morgan Coal Company of West Virginia and Kaiser Steel Corporation have been planning exploration as recently as 1970 would seem to indicate that potential values are thought to exist.[7] In a recent interview, a group of Japanese stated that they are in need of one million tons per year of low volatile or medium volatile coking coal[8]. There may, therefore, be a market for Alaskan coal.

A.2.1.3 Oil and Gas

It has become dramatically apparent during the last three years that potentially the economically most important arctic resource of the U.S. is the stored energy which exists in the on-shore and off-shore north Alaskan oil fields.

The major petroleum areas of Alaska are shown in Figures 2-7.[9] Of the several areas shown, only the areas north of the Yukon should perhaps be considered arctic. However, it is mainly in those arctic areas that the greatest reserves are believed to exist, and the most spectacular finds to

date have been in the North Slope area, where dramatic discoveries were made at Prudhoe Bay on the Atlantic Richfield - Humble Oil Co. lease in 1967.

Oil production in the state of Alaska has been significant only since 1957, but has increased notably in recent years. Production has been concentrated in the Cook Inlet area in southern Alaska. Crude petroleum output has increased in value during a three-year period as follows:[10]

1967	$88,187,000
1968	179,500,000
1969	214,464,000

Natural gas production has also increased, but not at a similar rate. Corresponding values were: [10]

1967	$ 7,269,000
1968	8,400,000
1969	12,665,000

It should be noted that the value of the 1969 oil and gas production was approximately 88 percent of the total value of all Alaskan mineral production for the year. Nevertheless, the total Alaska crude production in 1968 of about 66 million barrels was relatively minor in comparison with the one billion barrels produced in Texas alone [1]. However, the importance of arctic Alaska's oil and gas is not to be expressed in terms of present production but in terms of proved and potential reserves.

Aside from some gas production used locally from the Barrow and Gubic fields, the North Slope production now awaits resolution of the transportation problem. Meanwhile, exploration and some drilling has continued since the 1967 discovery at Prudhoe Bay.

As late as 1967 the total Alaskan reserves were estimated at only 381 million barrels.[1] (Total U.S. reserves were then placed at 31.377 million barrels). Of this about 80 million barrels were attributed to the North Slope, at Umiat and Simpson in the Naval Petroleum Reserve No. 4.[5] The discovery in the Prudhoe Bay area has drastically altered the reserve status. Since the end of 1967 numerous estimates have been made and high and low estimates have been produced. For example, The American Petroleum Institute and the American Gas Association, in outlining the U.S. oil and gas reserve position as of January 1, 1971 gave the following figures:[11]

U.S. total proved oil reserves -
38,001,335,000 barrels

Proved Alaska reserves -
10,148,824,000 barrels

Proved U.S. gas reserves -
290,746,408 mil cu ft

Proved Alaska reserves -
31,130,751 mil cu ft

Thus the proved Alaska reserves of which 9.7 billion barrels are attributed to arctic Alaska, were, for oil, 26 percent and for gas, 11 percent of the U.S. total. The estimates, which included North Slope reserves for the first time, moved Alaska from eighth to second among the states in oil reserves, and it was considered only a matter of time until Alaska moves ahead of Texas, which was credited with 13.2 billion barrels of proved

reserves. The estimated gas including 26 trillion cu ft of Prudhoe Bay reserves, placed Alaska third, behind Texas and Louisiana.

A monumental study by the National Petroleum Council on future petroleum reserves in the United States which appeared in 1970 [12] appraised the Prudhoe Bay, North Slope, reserves at 31.3 billion barrels in place, plus 43.5 billion barrels speculative in place, and estimated as recoverable about 30 billion barrels. It should be noted that the above estimates did not include NPR No. 4, the Wildlife Range, nor the Chukchi and Beaufort Sea offshore areas. Estimates for the NPR No. 4 reserves have been made, and range upward from 4.5 billion barrels, with the probability that that figure is much too low. [13] Offshore potential reserves have not been assessed for specific areas. However, the National Petroleum Council has been cited as estimated total U.S. potential offshore reserves out to a depth of 200 meters as possible 600-780 billion barrels of oil and 1,640 to 2,220 trillion cu ft of natural gas. A roughly equivalent amount is estimated for the 200 meter to 2500 meter depths. [14] The NPC has reported also that the U.S. has already drilled out to depths of 400 meters and has predicted that eventually the industry will be capable of drilling and producing in water depths of 4,000 to 6,000 ft (1200 to 1800 meters). The U.S.G.S. has recently conducted a reconnaissance marine geologic survey of the Chukchi Sea area of 55,00 square miles, and has reported structural features that suggest the need for further investigation of "what may be the western extension of the Barrow arch." [15] The Beaufort Sea is itself a promising area.

In summary, if one takes the 30 billion barrel estimate of North Slope recoverable reserves, and adds 10-15 billion barrels from NPR 4, plus an equal amount from the Wildlife Range, plus the offshore areas, the total for northern Alaska reaches totals of 50 to 60 billion barrels. Much higher figures are mentioned, especially for the offshore areas, but those are highly speculative for the present. It should be noted that estimates of proven reserves are lower than the above figures; the API total for Alaskan "proved reserves" being, as noted, just over 10 billion barrels.

The estimates of gas reserves in arctic Alaska are more speculative. The National Petroleum Council in 1970 estimated reserves of 238 trillion cu ft. [12] The American Gas Association "proved reserves" figure for January 1, 1971 was "only" 31 trillion cu ft. Potential reserves are obviously much greater, and estimates up to 432 trillion cu ft have been noted (See Figure 4). The estimates of 238 to 432 trillion cu ft may be compared with the National Petroleum Council estimated potential U.S. gas reserves at 1543 trillion cu ft. [17]

Thus is the National Petroleum Council estimates for total U.S. potential oil and gas reserves are taken as a base - 432 billion barrels of oil, and 1543 trillion cu ft of gas [17] - the arctic Alaska contribution to those totals might run as high as 14 percent and up for oil, and the gas percentage might run as high as 20 to 28 percent. It should, of course, be emphasized that these figures are unproven, and provide only speculative bases for projection into the petroleum future for the next 2 or 3 decades. The president of one U.S. oil company has forecast, for example, that

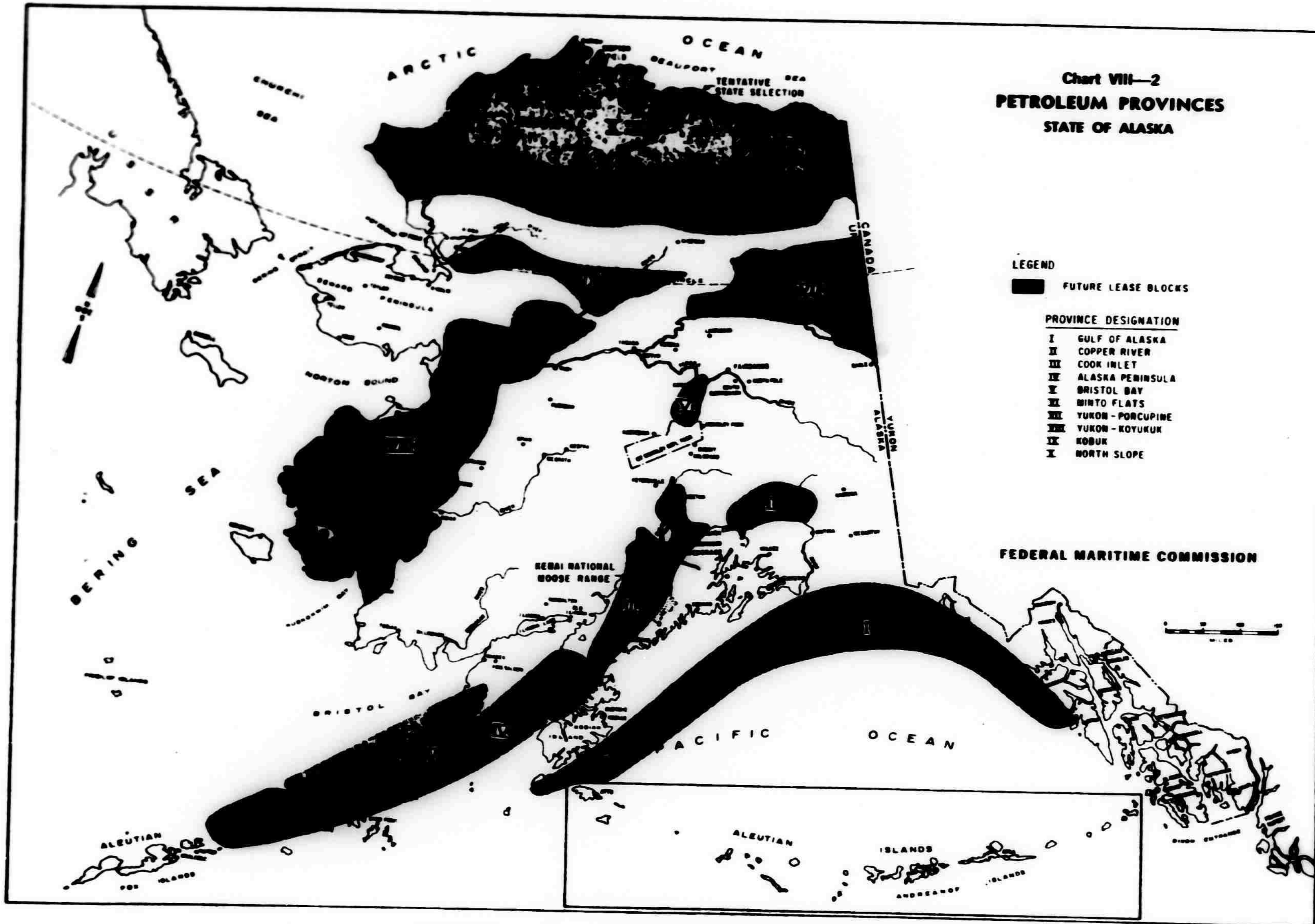


FIGURE 4 PETROLEUM PROVINCES

between now and 1990 the U. S. will consume 150 billion barrels of oil. At the present consumption rate of 5. 4. billion barrels a year the arctic Alaska reserve would perhaps equal U. S. consumption for 10 years. The anticipated increased consumption rate for oil - doubled or tripled by the year 2000 - would correspondingly reduce the number of years below 10. (18)

As has been noted, the production of oil and gas in northern Alaska awaits the provision of transportation facilities. The projected rate of production and delivery over the next decades, therefore, can only be calculated from plans, not hard facts. The pipeline (48 in) method has been estimated as capable of transmitting at increasing rates - up to 2 million barrels a day by 1980 (730 million barrels a year), and perhaps double that amount by 1990, if another pipeline were added. (19) Carrying the projected production - deliver onward to the year 2000, one finds that total delivery estimated, 1973 to 1990, would be roughly 14 billion barrels, and with two pipelines thereafter delivering 1. 4 billion barrels a year, the total delivery capacity 1973 - 2000 would be roughly 28 billion barrels. That is approximately the total conservative estimated North Slope reserve and about half the estimated potential reserves mentioned above for all of arctic Alaska.

A.2.2 Other Minerals

A.2.2.1 Met llic Minerals

Metallic mineral resources, particularly gold and copper, were main-

stays of the Alaskan economy from about 1880 until shortly after World War II.[7] The peak year for metal mining was 1916, when $48 million worth of metals was extracted in all of Alaska.[9] In 1963 the value of metals extracted was less than $8 million[9], and in 1967 had dropped to less than $7 million.[7] Some authorities expact a continuing decline, despite the fact that the metallic mineral resources of Alaska are large and varied. The extent to which Alaska's mineral wealth will be developed will in the long-term be dependent on the basic economic factors of prices and costs of production of additional units.[20] Northwestern Alaska is at a particular economic disadvantage in mining because of a short operating season, remote location (causing high shipping costs of materials) both in and out, high capital outlays required for facilities used under severe weather conditions, and high labor costs). Thus, mining in northwest Alaska is likely to continue to be restricted to certain scarce and valuable metals that can be marketed economically.

The known metal resources in the Alaska region are large and varied. (Figures 5 through 9 show the major metal deposits in Alaska.) To date, no significant amounts of metal mineral deposits have been reported north of the Brooks Range. However, there are unknown potentials in the enormous continental shelf areas off northwest Alaska. The crest and the North Slope of the Brooks Range, and the Arctic Coastal Plain are believed unpromising in this regard.[7] The area to the east and north of Kotzebue Sound has not shipped metallic ore. There has been some placer gold production along the Kobuk River, and occurrences of iron ore, nickel, and lead are known at Ruby Creek.

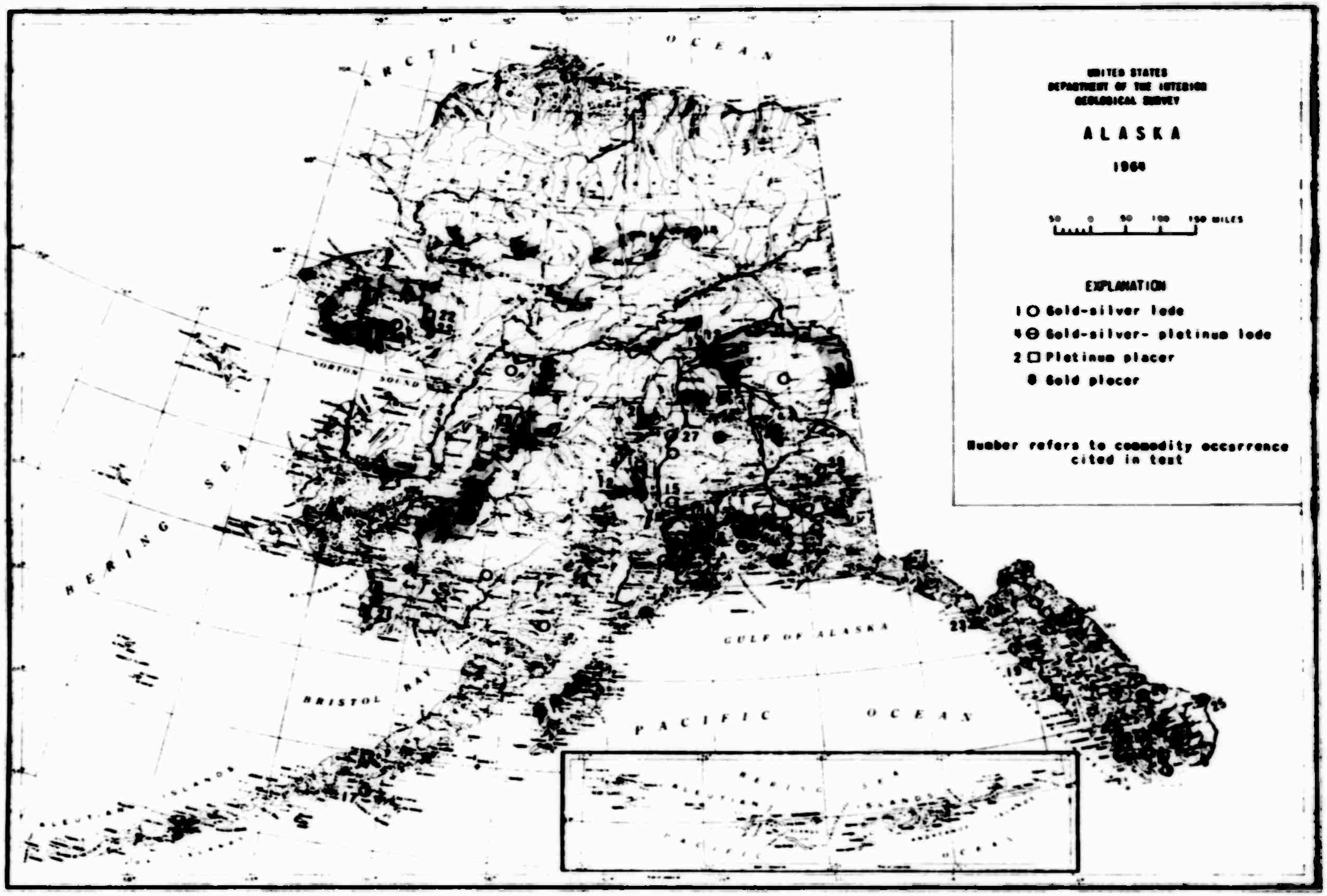


FIGURE 5 GOLD, SILVER, AND PLATINUM IN ALASKA

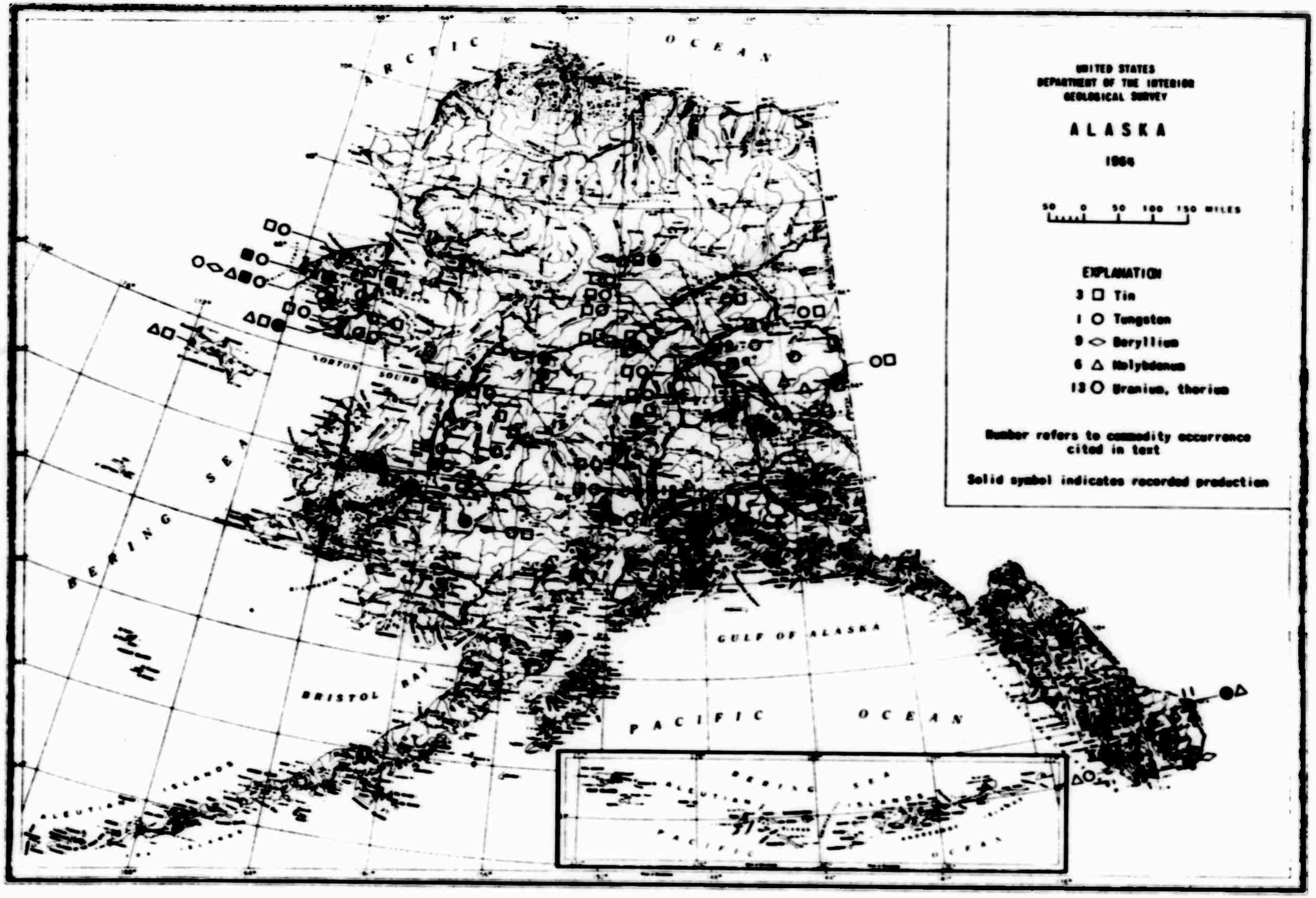


FIGURE 6 TIN, TUNGSTEN, BERYLLIUM, MOLYBDENUM, URANIUM, AND THORIUM IN ALASKA

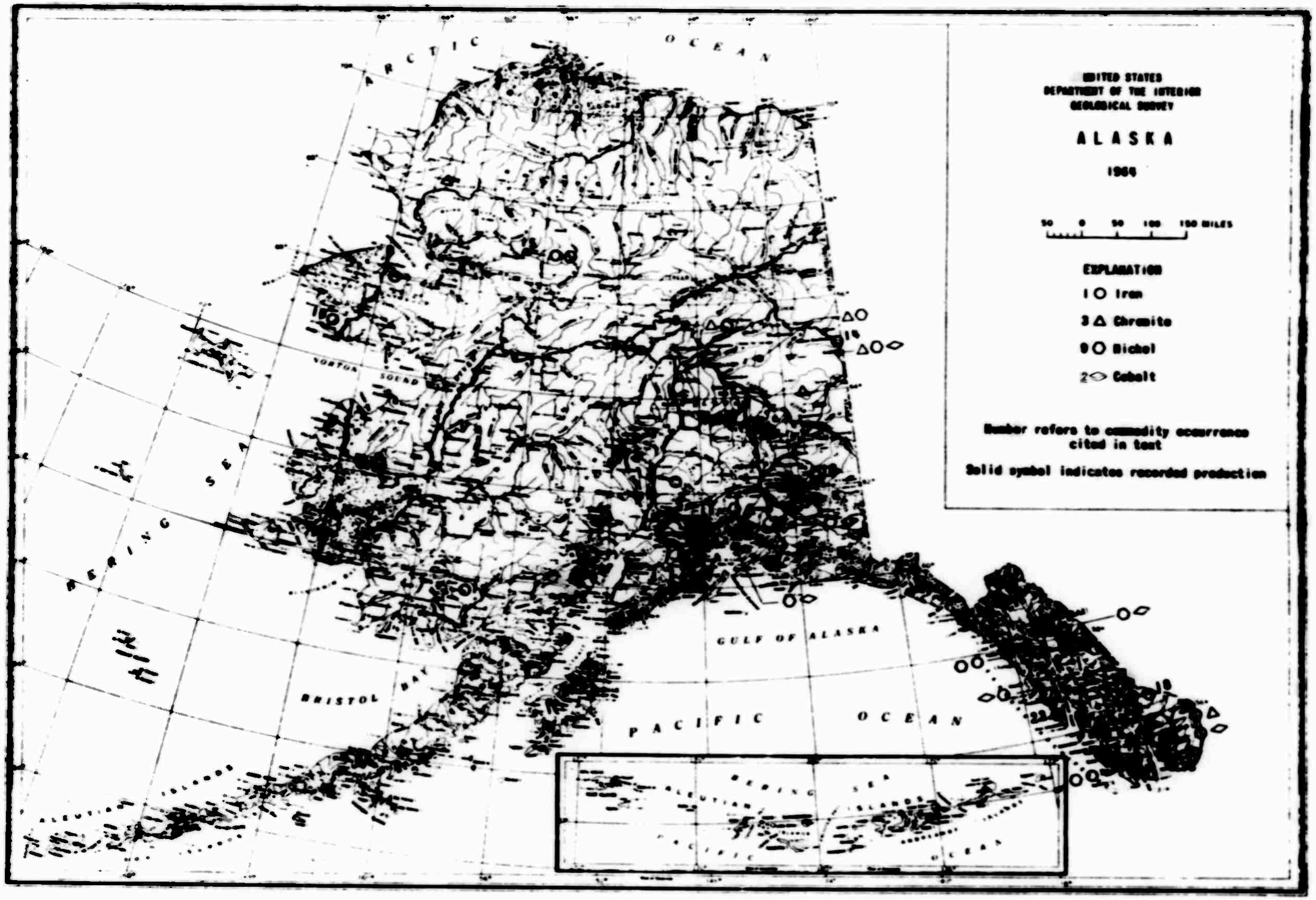


FIGURE 7 IRON, CHROMITE, NICKEL, AND COBALT IN ALASKA

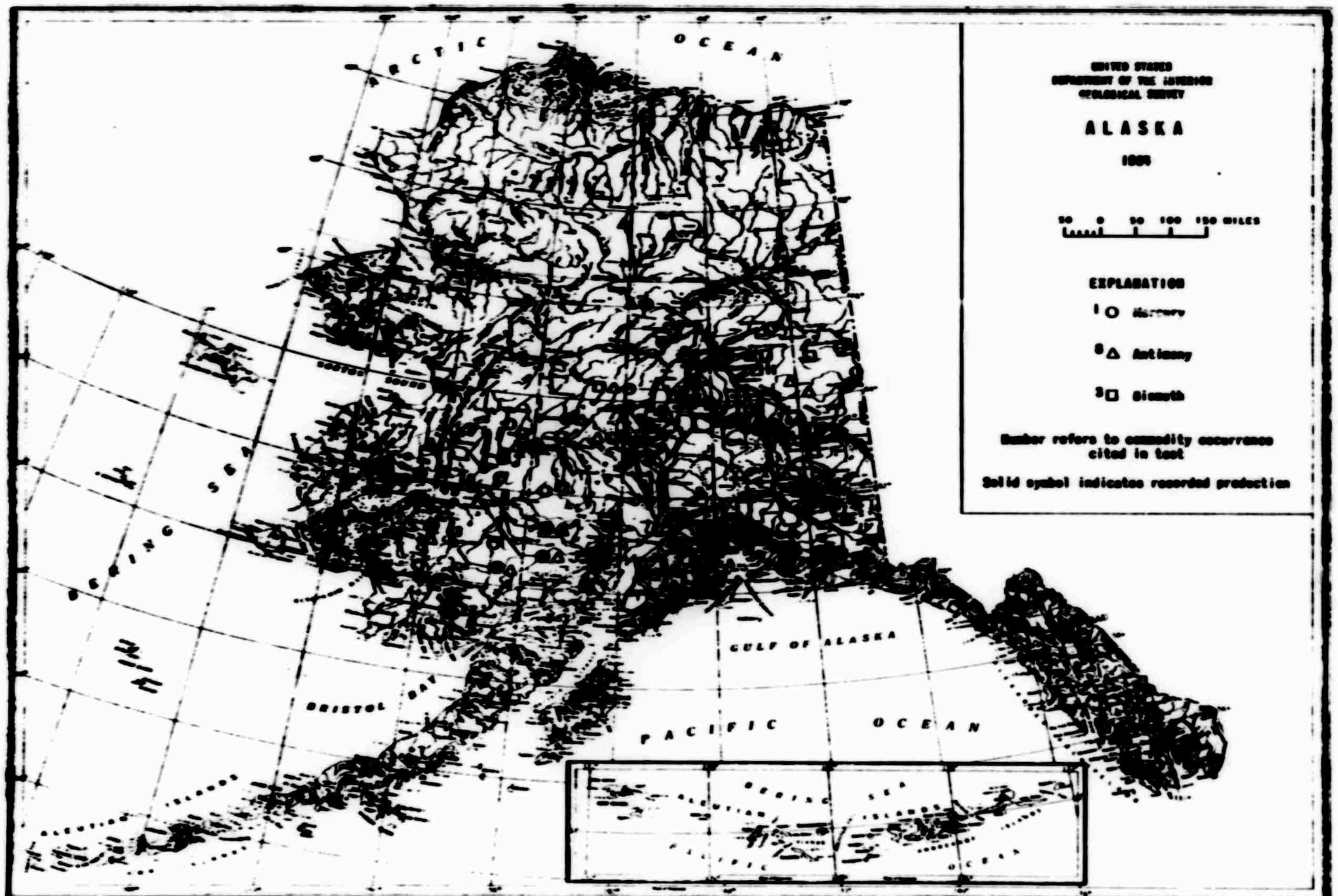


FIGURE 8 MERCURY, ANTIMONY, AND BISMUTH IN ALASKA

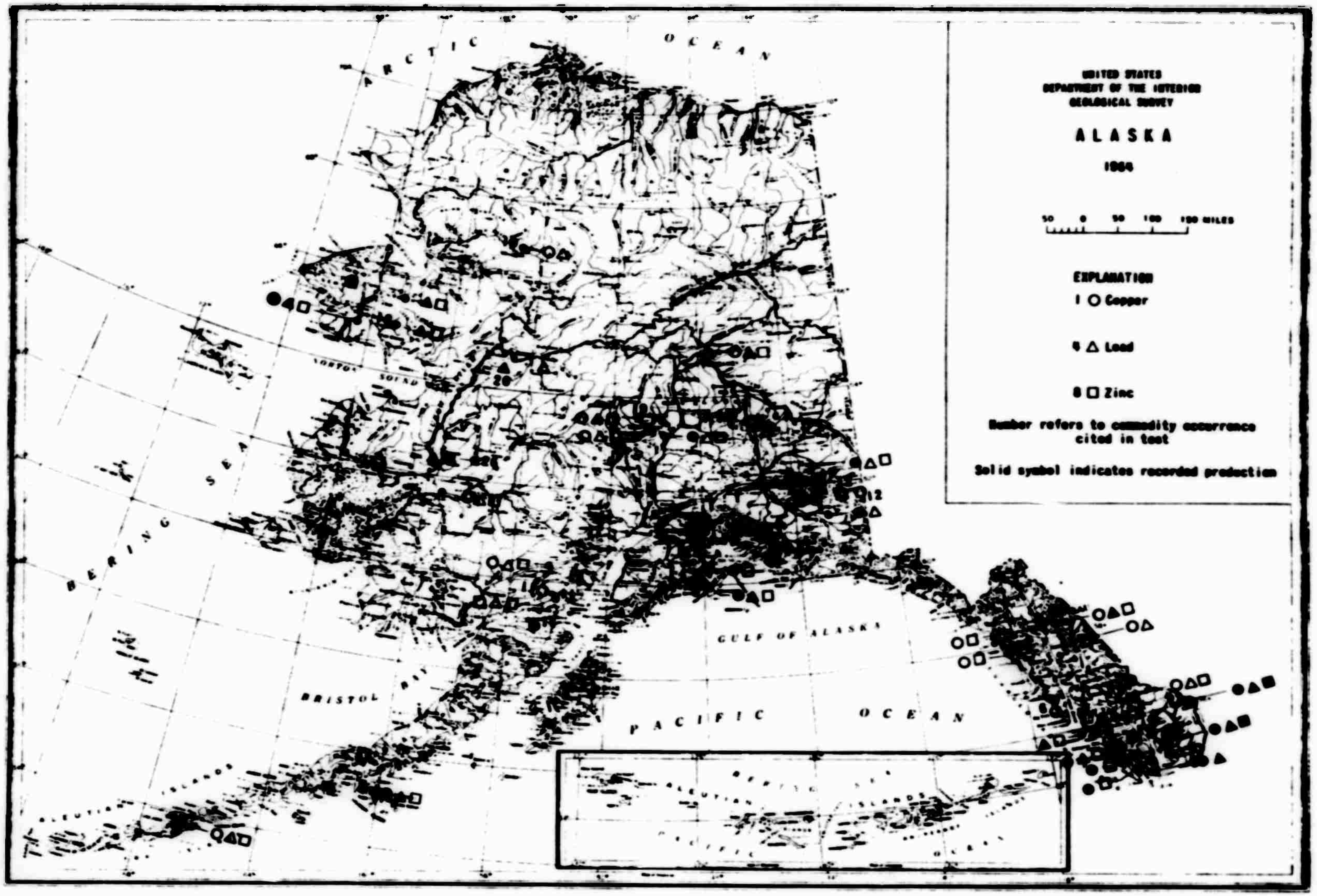


FIGURE 9 COPPER, LEAD, AND ZINC IN ALASKA

The largest known arctic Alaskan copper reserve of 100 million tons of 1.2 to 1.6 percent copper ore occurs in the Ruby Creek area. Estimated potential production is 60,000 tons of copper concentrate annually.[9] The concentrate might be barged down the Kobuk River to Kotzebue, during the summer months. Kennecott Copper Corporation owns the deposits. The U.S.G.S. has recently reported a copper deposit estimated at more than 200 million tons in the Orange Hill area in the Nabesna Glacier district in eastern Alaska. The copper ore in Alaska, as elsewhere, is mixed with varying amounts of gold, silver, lead, and zinc.

Other metallic minerals in Alaska are iron ore, antimony, tin, tungsten, bismuth, mercury, and platinum. Most of these are not found in arctic Alaska, unless the Yukon River area is included. A small high-grade residual iron ore deposit has been found near Nome, with 0.5 to 1.0 million tons of 10 to 45 percent iron. [5]

The potentially significant metals of the arctic or near-arctic region of Alaska are copper at Ruby Creek; gold, tin and tungsten in the Seward Peninsula, and mercy in the Kuskokwin River Basin. The copper concentrate production potential of 60,000 tons annually at Ruby Creek would not be immediately critical to the nation's economy, since over one million tons has been produced annually in recent years by the U.S.; with about 500,000 tons from Arizona alone. [21] However, long range forecasts of the copper demand through the year 2000 are 50 percent above proven resources. [22] Assistant Secretary Hollis M. Dole of the Department of the Interior has forecast a tripling of the U.S. demand for copper by 2000. [23] Thus the copper at Ruby Creek could become economically and strategically important

in the next decades.

Production and reserves of tin, tungsten and mercury in Alaska are not great, although a potential production figure of 5,000 flasks annually of mercury in the Kuskokwim area makes it a significant potential source of that metal.

In the near future the arctic Alaska metal of significance could be mercury and, in the longer range copper may be increasingly important.

A.2.2.2 Non-Metallic Minerals

The production and known resources of non-metallic minerals in arctic Alaska are limited, as shown in Figure 10.[5] One of these is asbestos. Deposits at Kobuk have shown limited potential, and in 1960 the U.S.G.S. announced a discovery in the Yukon-Tanana upland near Eagle on the Alaska-Yukon Territory border. No estimate of reserves were given for the find, which was 60 miles west of the newly-opened Clinton Creek deposit by Cassiar Asbestos on the Canadian side.[4] Estimated fluorite reserves at Lost River have recently been upped from 2 million to 10 million tons by the U.S.G.S.[21] Annual production in the U.S. amounted to 250,000 tons in 1966. Hence the Alaska reserves might well be significant in this resource which has importance to the aluminum and steel industries. A world-wide shortage is said to exist, and the trend is toward greatly increased consumption of fluorite.[23]

Extensive resources of predominantly low to medium grade (8% to 25%) phosphate rock occur in the central portion of the Arctic Slope of Alaska

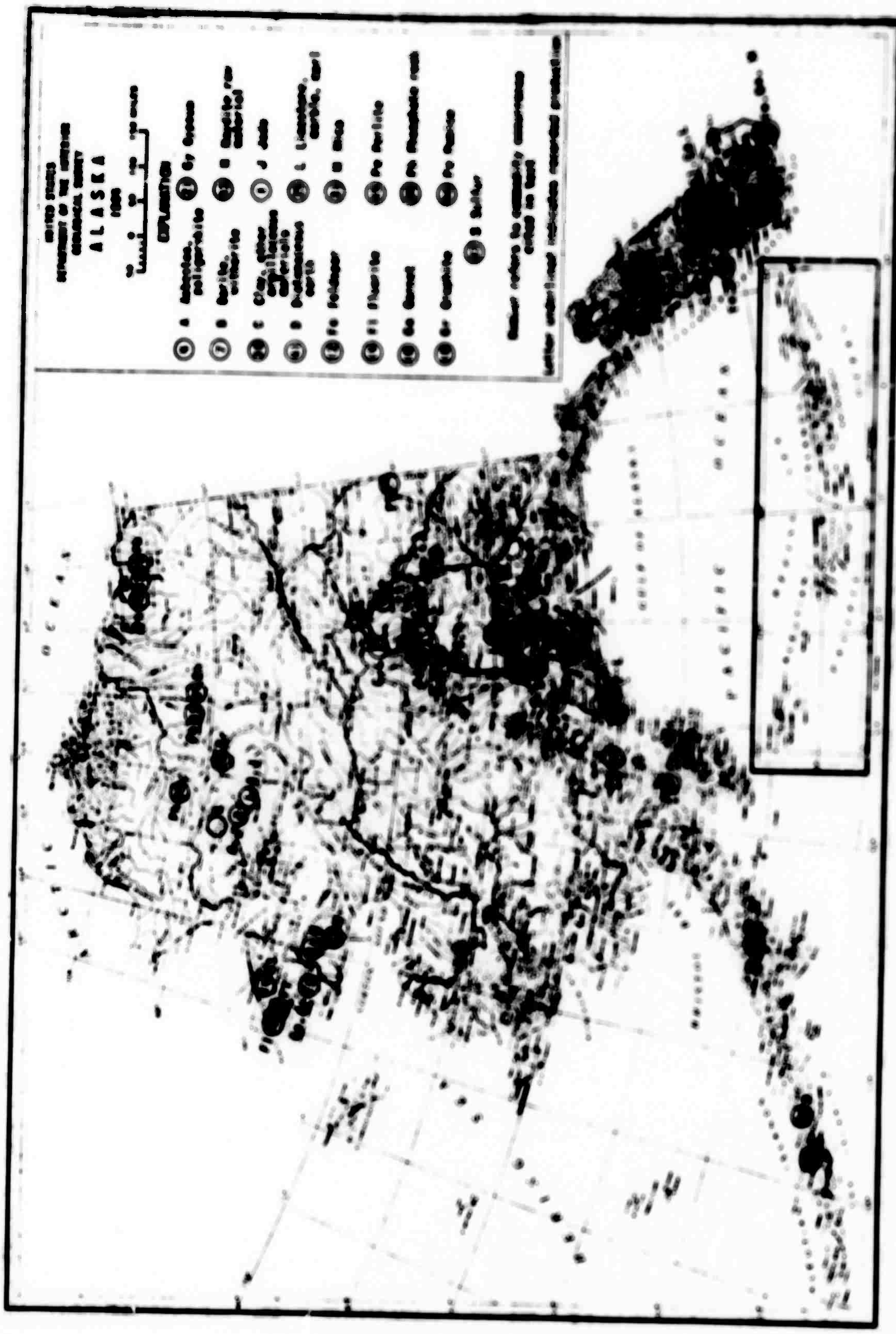


FIGURE 10 NONMETALLIC MINERALS IN ALASKA

in the Tiglukpuk Creek - Kiruktahiok River area, and substantial amounts of phosphate rock of unknown thickness and grade are indicated in the eastern Brooks Range.

There has been a limited graphite production in the Kigluack Mountains of the Seward Peninsula. Reserves are estimated at 65,000 tons of rock containing 52% of graphite. [5]

Other known non-metallic minerals in the area include barite, with 41 claims filed upstream from Circle City in 1969; and garnet, as well as mica found on the Seward Peninsula. In recent years the second-ranking mineral producer in Alaska has been sand and gravel. Production figures for 1969 show that the value of petroleum production alone was higher, with sand and gravel production valued at $18,615,000, down slightly from 1968. [12] If and when the trans-Alaska oil pipeline and the service roads are built in northern Alaska, the sand and gravel supplies will be much needed, and in considerable quantities.

A.2.3 Other Natural Resources

The areas of Alaska bordering those parts of the ocean that are ice-covered a significant portion of the year include the area north of the Brooks Range, the Seward Peninsula, the lowlands of the Yukon and Kuskokwim Rivers, and the Bering Sea islands. Much of the region is treeless tundra with permafrost.

Subsistence hunting and fishing are basic to the economy of this region. Hunting and trapping of fur-bearing animals provide the main winter income for many people. The median family income is very low. There has been no significant commercia production of timber or fish in this northwest region and none is anticipated. The principal resources of arctic Alaska are, as stated, its minerals.

A.2.4 Population

The areas of Alaska bordering the Arctic Ocean, Chukchi Sea and Bering Sea are very sparsely populated. The land areas of interest in Alaska include that north of the Brooks Range, Kobuk River Basin, Seward Peninsula, and the Yukon River Basin bordered on the south by the Kuskokwim Mountains, as shown in Figure 1.

It is estimated that in the middle 1960's about 30,000 people, consisting mostly of Eskimos, lived in this far north and far west area. This compares with a 1970 total state population slightly over 300,000. The Northwestern senatoral district had a 1964 population of 14, 912. (25) To this must be added the western portion of the Central distric which had a population of

60, 990. Most of the population of this district is centered around Fairbanks, so it is estimated that the western part has only about 15, 000 people. Less than 10, 000 people live above the Seward Peninsula and north of the Brooks Range. About 1,000 men have been on the North Slope for oil drilling.

Table 1 shows the major towns in the far north.[25] The largest town is Nome on the Seward Peninsula with a population of 2,316. Other major towns include Barrow in the north, Kotzebue on the Chukchi Sea, and Bethel on the Kuskokwim River.

It is projected that the total population of Alaska will be nearly 400,000 by 1980.[26] This is expected to result from petroleum development and production on the North Slope, continued growth of forest products industries, and stabilization and diversification of the fish products industries. Of a total anticipated civilian workforce of 159,800 in 1980, the oil and gas industry is expected to employ 4,300 and mining 2,400.[27] Most of the manufacturing related to North Slope petroleum production should take place around Anchorage where a growing petrochemical complex and other factors make the prospect an economic operation. Even so, the area from Fairbanks north should have a population increase from 68,000 in 1969 to 96,000 in 1980.

Table 1 TOWNS IN FAR NORTH ALASKA

(above 100 in population)

Barrow	2,201	Wainwright	274
Kotzebue	1,656	Kiana	216
Noorvik	384	Kivalina	142
Selawik	348	Shungnak	135
Point Hope	324	Kaktovik	124
Noatak	275	Anaktuvuk Pass	107

A.2.5 Transportation

The Alaskan transportation net is made up of motor roads, railroads, rivers, sea routes, air modes, and pipelines for oil and gas. Figure 11 shows the Alaskan roads and airports. (28) Figure 12 shows the coastal traffic. (16) Motor roads and railroads are used in the south central region, while shipping and aircraft are used throughout Alaska. Ships and barges accounted for most of the tonnage to, from, and within Alaska. (16) About 15 percent is moved by the Alaskan Railroad. Truck and air accounted for only a few percent.

A.2.5.1 Shipping

Due to severe ice conditions ocean access to the northwest is limited to summer months. Traffic flow to and from this region amounted to 71,000 tons or 7 percent of total Alaskan traffic in 1964. (16) Movements northbound

consisted of general commodities, while southbound movements were primarily fish. About one-third of the total tonnage was southbound. Commercial cargo moves almost entirely through Dillingham, Bethel, Kotzebue, and Nome. Only Bethel has the dock facilities or water depth to accommodate large vessels. The other towns must use lighterage vessels for cargo transfer.

Seasonal activity from May to October is possible along many of Alaska's navigable rivers. Recent movements in the northwest region have occurred on the Innoko, Kobuk, Koyukuk, Kuskokwim, Kvichak, Noatak, Nushagak, and Yukon Rivers. Traffic has been from 30,000 to 50,000 tons in recent years.[16] Shallow-draft vessels carry general cargo, equipment, supplies, minerals, and furs.

The activity of oil companies on the North Slope in recent years has changed the structure of the shipping in the northwest. The ocean route up around Point Barrow is open for about 6 weeks. Arctic Marine Freighters delivered 100,000 tons of cargo to the North Slope in the summer of 1969.[29] In the summer of 1970 the water-borne shipment from Seattle to the North Slope (3,200 miles) was 185,000 tons of oil held and construction materials.[30] Twenty-one tugs and 41 barges were involved in the northbound tow of 25 days. Included were 117,000 tons of 48-inch trans-Alaskan pipeline, 6,000,000 gallons of bulk fuel, and 45,000 tons of general cargo for Prudhoe Bay.

Point Barrow is a bottleneck in the North Slope shipping because the polar ice pack is never far offshore. It has been suggested that a ship canal be built through the low, level, lake-studded terrain south of Barrow, exiting in Admiralty Bay or, if necessary, going to the Smith Bay, bypassing Cape

Simpson. [31]

Barge shipping also flows on Canada's Mackenzie River and along the Beaufort Sea to Prudhoe Bay. In 1969, 206,000 tons were shipped on the Mackenzie River and annual tonnages were increasing. [32] Some of this cargo went to the Canadian drilling sites. At the rate of $80 -$125 per ton from Seattle, barge transportation to the North Slope is still the cheapest. Air transport can range up to $170 per ton from points in Alaska. Truck rates over the winter road, when it was in use, were running as high as $240 per ton. In the future, the barge traffic to the North Slope is expected to continue to increase as the petroleum fields are developed.

There is the future possibility of super tankers brining oil from the North Slope through the Northwest Passage or around Greenland to the East Coast market. The Newport News Shipbuilding and Dry Dock Company was awarded a contract in the spring of 1970 by Humble Oil and Refining Company to develop a design for these icebreaker super tankers. [33] The contract contains options for tanker construction and licensing provisions that would permit Newport News Shipbuilding to use the Humble design for other customers.

Each of these giant icebreaker tankers would displace 250,000 dead-weight tons and could haul between 1.5 and 1.75 million barrels of oil. A fleet of 30 to 40 super tankers - each costing $60-$90 million - could carry 2 million barrels of oil per day by 1980. [34] The cost of moving oil by tanker to the East Coast has been estimated to be $.60 per barrel lower than by a transcontinental pipeline. [26] The decision to build the super tanker fleet has not yet been made, however, by Humble Oil Company.

Since the waters off the North Slope are shallow, the super tankers

would have to anchor 6 to 25 miles from the coast. Bringing the oil out from the coast and providing permanent terminals is a key problem. Ice islands and Herschel Island have been suggested.

An alternate method of shipping the oil by 170,000 ton nuclear-powered submarine tankers has been proposed by General Dynamics Corporation. [35] Costs for such a submarine tanker may be as much as $175 million. The company says they could be ready in 3 to 5 years. [36]

A.2.5.2 Railroads

There are no railroads serving Northwest Alaska or the North Slope. The existing Alaska Railroad is 483 miles long from Seward to Fairbanks. An additional 54 miles of branch lines serve the coal mines and military installation. In fiscal yet 1963-64, the railroad carried a total of approximately 1,507,000 tons, for an average haul of 138.6 miles. [16]

The North Commission has recommended that the railroad be extended to the Umiat area on the North Slope, and Kobuk on the South Slope of the Brooks Range. [37] Whether this extension will be achieved depends partly on the results of the current $3 million transportation corridor survey underway. [37]

A.2.5.3 Motor Roads

There are few roads in Alaska, most of them are concentrated in the south central region. Over 75 percent of Alaska's area is more than 100 miles

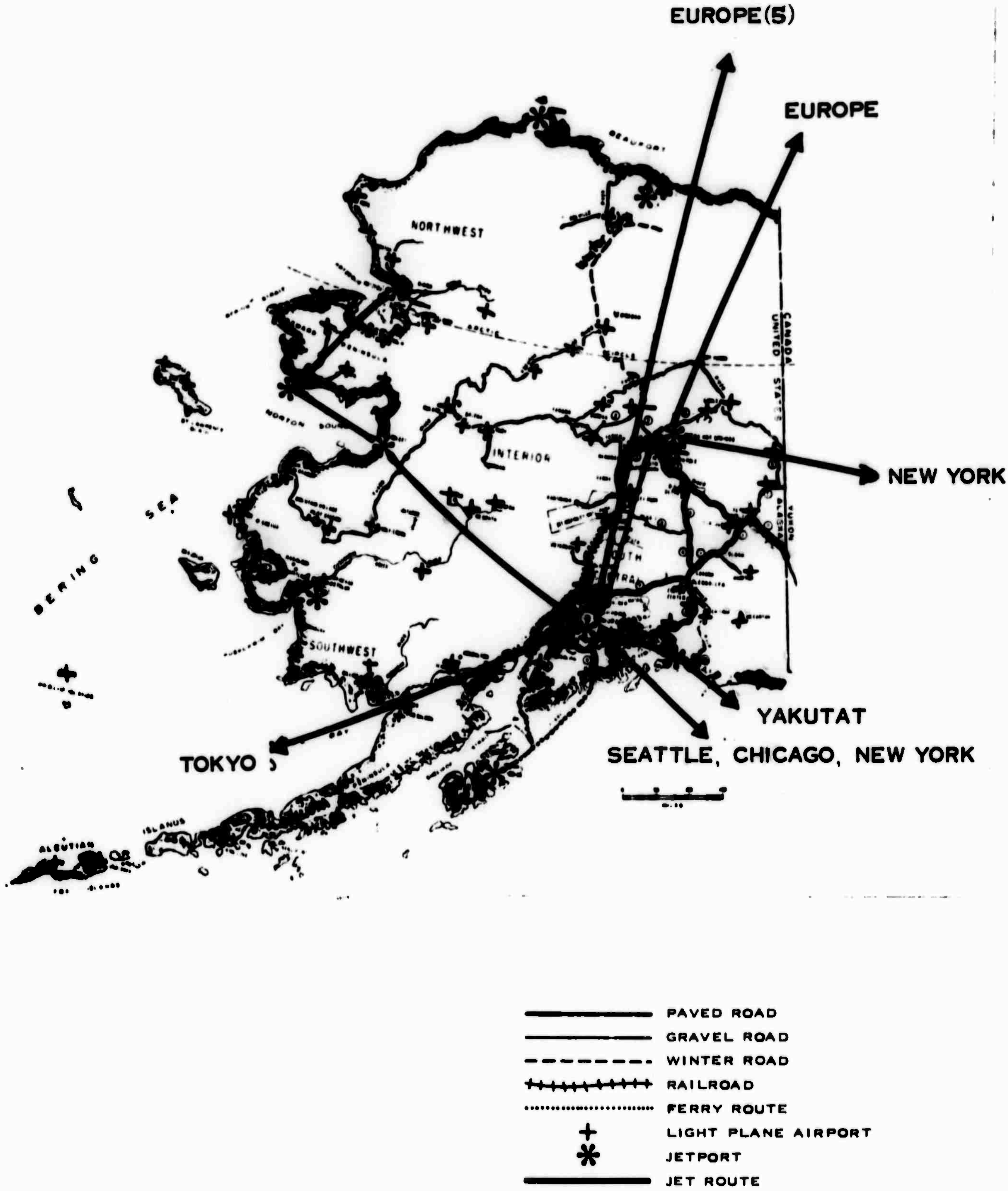
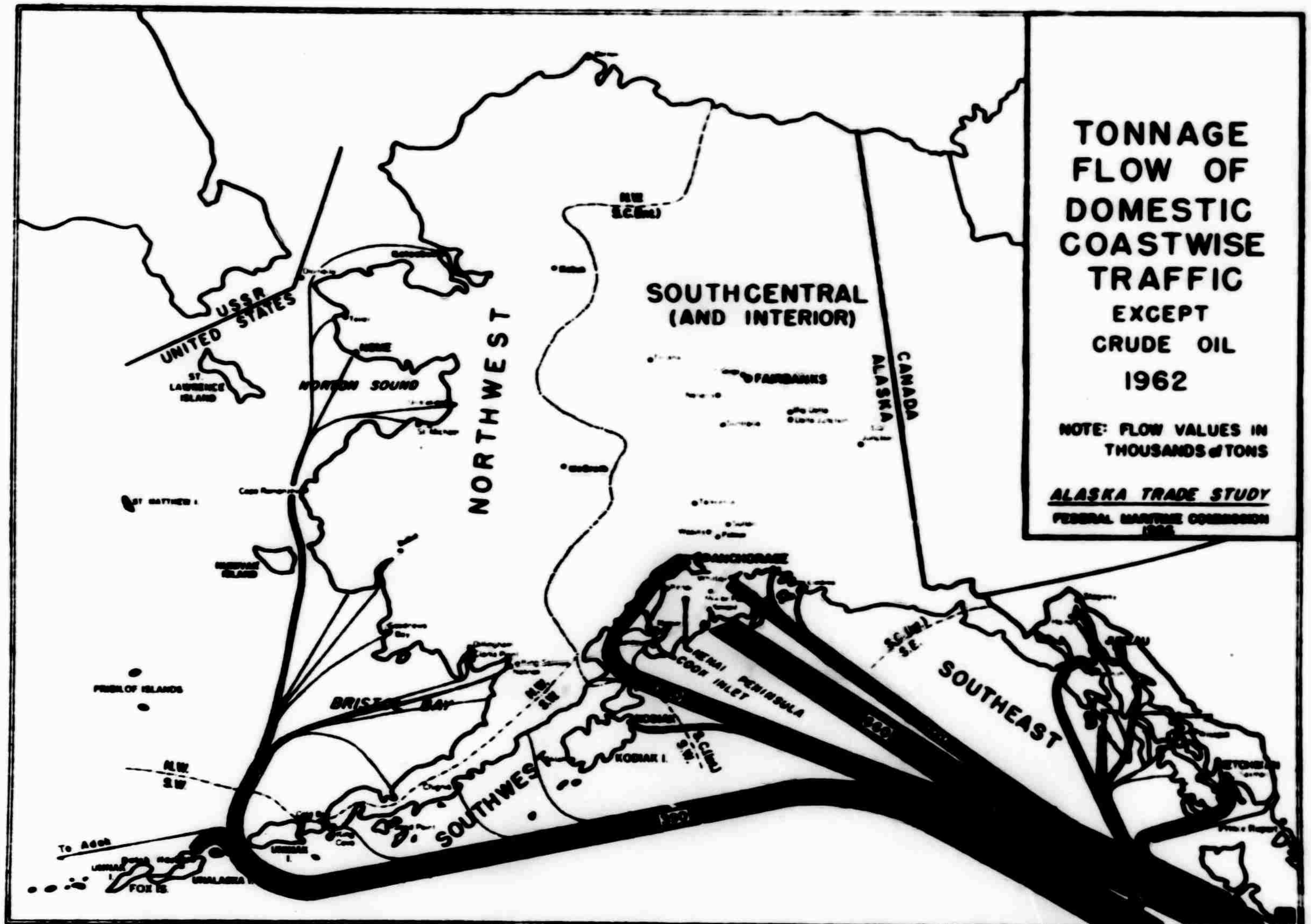


FIGURE 11 ALASKAN ROADS AND AIRPORTS



SOURCE: TRANSPORTATION CONSULTANTS, INC. AND WILBUR SMITH AND ASSOCIATES. ALASKA HIGHWAY STUDY PREPARED FOR U.S. DEPARTMENT OF COMMERCE, BUREAU OF PUBLIC ROADS, 1965

FIGURE 12 TONNAGE FLOW OF DOMESTIC COASTWISE TRAFFIC

from any road. By the end of 1962, Alaska had 1, 209 miles of paved and 472 miles of unpaved Federal-aid primary highway system. At that time there were also 1, 721 miles of secondary roads, of which 98 percent were unpaved.

In the northwest, gravel roads exist from Nome to the towns of Teller, Taylor, and Council. A gravel road connects Ophir with McGrath and Poorman with Ruby. A winter ice road was opened in the spring of 1969, connecting Livengood above Fairbanks to the North Slope area around Umiat. Three hundred forty-three trucks carried 7, 464 tons of equipment and supplies for this 420 mile road to the North Slope in the spring of 1969 before the April 15 thaw forced closing of the road. [29] Another 139 vehicles, mostly scrapers and dump trucks, were sent up the road to be used by the oil companies on the North Slope. Truck freight costs were roughly the same as those incurred by air shipment, except that trucks can deliver goods to the work site and do not require the extra handling costs from airport to work site.

The future northwest traffic may be substantially increased by the petroleum activity on the North Slope. Sixty miles of an all season road to the North Slope following the proposed path of the Alyeska pipeline had been completed by the summer of 1970 before work ceased because of the permit delay. Road networks will expand on the North Slope as the oil fields are developed.

A.2.5.4 Air Routes

Alaska has more general aviation aircraft per capita than any other state - one aircraft for each 100 residents.[30] Because of the lack of roads over much of the state, passenger and freight transportation by scheduled airlines, chartered, and private aircraft are all important. There are many small gravel airports throughout the state that serve light aircraft and the larger Hercules air freight aircraft. In addition, commercial airlines maintain scheduled passenger flights with many major towns using a variety of propeller aircraft. Jet aircraft serve Cordova, Anchorage, Fairbanks, Nome, Kotzebue, Barrow, Deadhorse, Prudhoe Bay, Bethel, and Kodiak with scheduled flights. Anchorage is also linked to Europe, Tokyo, Seattle, Chicago, and New York. Fairbanks is linked to New York and Europe.

Aircraft are playing a significant role in the North Slope activities. They can operate all seasons - in the winter when the rivers and seas are frozen and in the summer when the tundra becomes swampy. Complete drilling rigs have been moved to the North Slope via aircraft. Aircraft will continue to play a key role in the north for movement of personnel and critical freight. The Boeing Company is even advancing an idea of moving North Slope oil by containerized aircraft.[36]

A.2.5.5 Pipelines

Pipelines will play an important role in the transportation of oil and gas

within and from Alaska. Small pipelines are currently used in the south-central region for transporting petroleum from producing fields. Future emphasis will be on large pipelines to transport oil and gas from the North Slope to U.S. markets on the east coast, midwest, and Pacific coast.

A Trans-Alaska Pipeline System (TAPS) Company was formed by several oil companies to transport the oil from Prudhoe Bay to the port of Valdez (800 miles) (see Figure 13). This 48-inch line is expected to cost approximately $1.3 billion and to have an initial capacity of 500,000 barrels per day and eventually a maximum capacity of 2 million barrels per day with 12 stations. [32] The proposed pipeline route is over extremely rugged and difficult terrain and in an area of extreme environmental conditions. TAPS encountered difficulties in obtaining the necessary releases and rights of way to proceed. As a result of pipeline being delayed, TAPS was dissolved and the Alyeska formed in 1970. The planned pipeline would serve primarily the U.S. pacific coast markets using conventional tankers from Valdez.

The pipeline would be laid through the earthquake belt, across 200 miles of marshy tundra, and 300 miles of permafrost, forest, and swollen glacial rivers. Temperatures range from 80° below in winter to 90° above in summer. Before reaching Valdez, the proposed line will climb the Alaskan Range where even the lowest passes are raked by 100 mile an hour winds. The next barrier is the Chugach Mountains where winter snows often measure 10 feet. The pipe must be laid in such a manner as not to melt the permafrost which could cause breaks in the pipeline. The oil must be heated to flow under the cold environmental conditions. There also has been concern about the

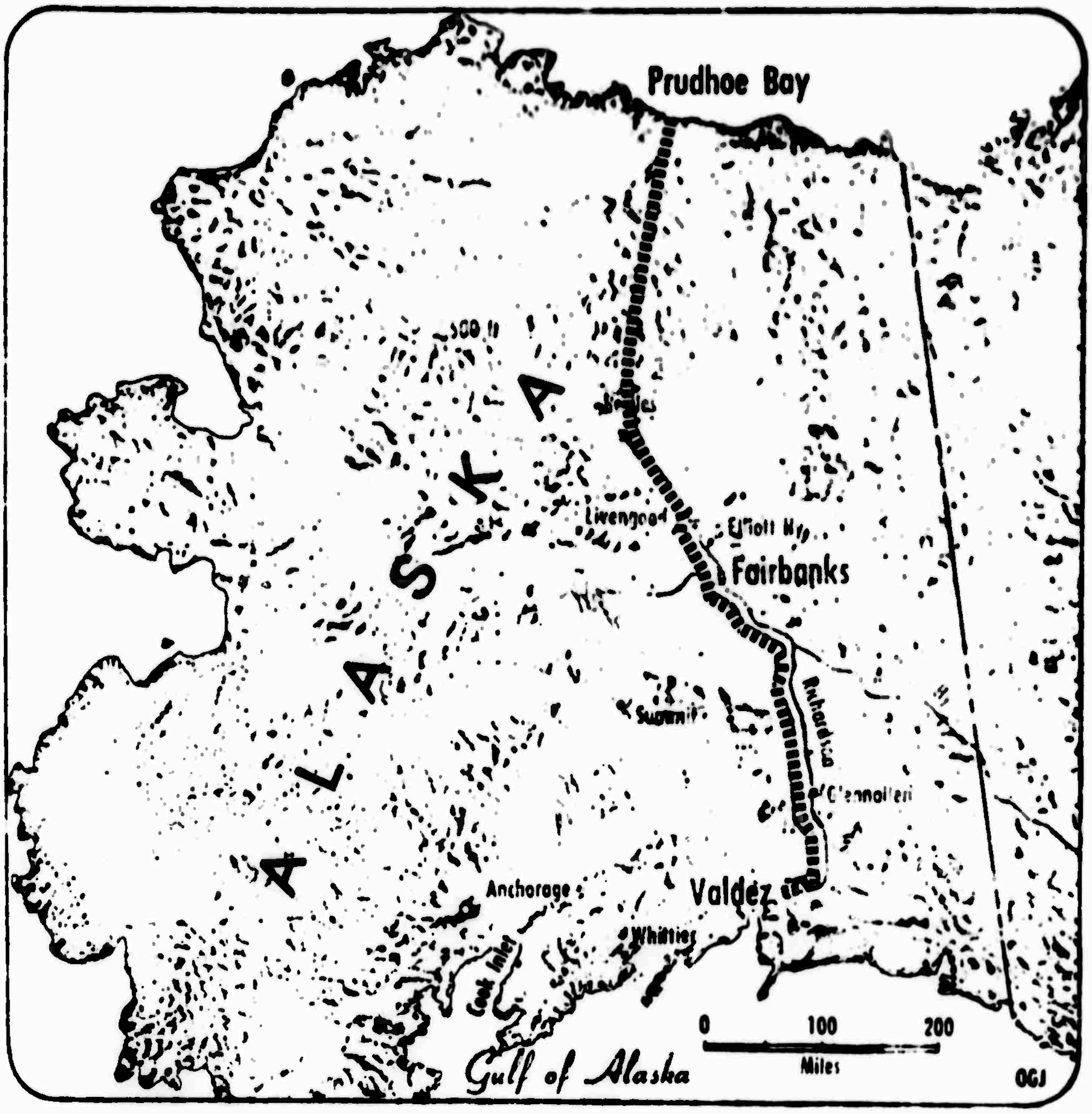


FIGURE 13 PROPOSED ROUTE OF THE TRANS-ALASKA PIPELINE

FIGURE 14 PROPOSED MACKENZIE VALLEY CRUDE LINE

probable interference with caribou migration pattern. There are native claims on the land which Congress is presently trying to settle. The extended delay in the granting of a permit suggests that it cannot be in service before 1973 or 1974.

The Mackenzie Valley Pipeline Research Co., Ltd., composed of four oil and two pipeline companies, was formed to explore the merits of laying a 48-inch crude line from the North Slope to Edmonton, Alberta. The proposed line would generally follow the Mackenzie River from the Arctic coast south. At Edmonton, the line would connect with existing facilities of Trans-Mountain and Interprovincial Pipeline Companies serving the mid-west area. The proposed route would cross several hundred miles of permafrost (see Figure 14). [33] A proposed gas line would be laid simultaneously with the Mackenzie Valley Pipe Line or parallel to it. [39]

A fourth proposed pipeline is for the transportation of gas from Prudhoe Bay to markets in the midwestern U.S. and in Canada. That line would be built in three segments and would be a 48-inch pipeline extending for 1,550 miles from Prudhoe Bay to a point in Alberta where it would connect with Alberta gas trunk's existing 2,800- mile transmission system. From Alberta the gas would be connected to major pipeline systems for export to U.S. and Canadian markets. The pipeline would have an initial capacity of 1.5 billion cu ft of gas daily, rising to 3 billion cu ft daily by 1980. Completion of the first phase is projected for 1974. [40]

A.3 CANADIAN ARCTIC RESOURCES

A.3.1 Energy Resources

A.3.1.1 Coal

Among the economically significant energy resources of arctic Canada coal is not included. Production north of 60^{o} has been confined to the Yukon Territory where coal production reached a high annual value of $123,675 in 1963. By 1968 production of coal was no longer indicated in the mineral production statistics for the Territory. (41) 1969 statistics similarly failed to record any coal production. (42)

A 3.1.2 Water Power

In the Yukon Territory and the Northwest Territories water power is of special importance in the development of mining areas such as Mayo and Yellowknife. In the Yukon, most water power resources are on the Yukon River and its tributaries. Although thorough surveys have not been made, recent partial surveys show that the rivers flowing into the Great Slave Lake and the South Nahanni River, which drains into the Mackenzie River, have considerable potential. (43) Currently there are four hydroelectric generating plants operating in the Yukon, and a like number in the Northwest Territories.(41) The potential water power development of arctic Canada may be gleaned from a 1970 statement by the Northern Economic Branch of the Canadian Department of Indian Affairs and Northern Development that, "In total, the water flow in

these four principal (sic) basins is approximately equal to two Fraser Rivers, one Columbia River and one St. Lawrence River. The future requirements for water in municipal and industrial development is therefore well assured if proper care is exercised in resource development." [41] It should be emphasized that hydroelectric power is of much greater significance in the Middle North than in the Far North. That is not to say that power lines may not penetrate the Arctic from sources farther south. Table 2 [43] shows preliminary statistics for installed hydro- and thermal-electric generating capacity by province (1968).

A.3.1.3 Nuclear Thermal Power

Development of commercial power generation in thermal plants using heat generated by nuclear reactors is a major contribution of Canada to energy resource technology. That development has centered around the CANDU reactor which uses a natural uranium fuel with a heavy water moderator. However, all three major nuclear power plants are in southern Canada.

A.3.1.4 Oil and Gas

Oil has been produced at Norman Wells in the Mackenzie Valley from the middle of the 1930's to the present. Current annual production is only about 750,000 barrels. In the area south of Norman Wells, oil and gas exploration activity has been building up over the past four or five years. That activity is actually an extension of activity in northern Alberta and

TABLE 2 INSTALLED HYDRO- AND THERMAL-ELECTRIC GENERATING CAPACITY, BY PROVINCE, BY DECEMBER 31, 1968[1]

	Hydro	Thermal	Total
	Thousands of kilowats		
Newfoundland	819	112	931
Prince Edward Island	---	77	77
Nova Scotia	163	543	706
New Brunswick	562	551	1,113
Quebec	11,035	762	11,797
Ontario	6,413	4,876	11,289
Manitoba	1,184	369	1,153
Saskatchewan	586	691	1,277
Alberta	616	1,435	2,051
British Columbia	3,531	1,515	5,046
Yukon Territory	18	15	33
Northwest Territories	35	26	61
CANADA	24,962	10,972	35,934

[1]Preliminary.

northeastern British Columbia. [44] A pipeline is being built to the Beaver River and is expected to be extended to Pointed Mountain later.

Major oil production in Canada today is south of the arctic region, including the rich Athabasca tar sands. It does not impact directly on the importance of the Canadian Arctic. However, this production has led to the construction of high capacity pipelines, e.g., from Edmonton, Alberta toward the Chicago area in the U.S. These pipelines may well have significance for the future transportation of oil and gas from the Arctic.

The Prudhoe Bay 1967 discoveries in Alaska had immediate repercusions in Canada. Potential oil and gas finds in arctic Canada had long been the subject of mild interest, and extensive leases had been registered by several oil companies. After 1967, however, Canadian arctic exploration and drilling was given explosive encouragement. Panarctic Oils, a consortium with government capital input was organized as an instrument for the early prosecution of intensified activity. The basis for the interest and activity was mainly the simple fact that the geologic features of the Canadian arctic region, including particularly the Mackenzie Delta region, the Arctic Islands area, and the Sverdrup Basin (see Figures 15 & 16), were known to have promising geologic formations as did those of the Alaska North Slope and were therefore attractive to oilmen. [45] To summarize, in the year 1970, 72 wells were drilled in the Northwest Territories, the Yukon, and in the Arctic Islands for a total drilling of 369,885 feet. [8] High-pressure gas and some indications of oil have been found by Panarctic Oils in 1969 at Drake Point on Melville Island. Panarctic has also, on March 25, 1971, spudded the world's

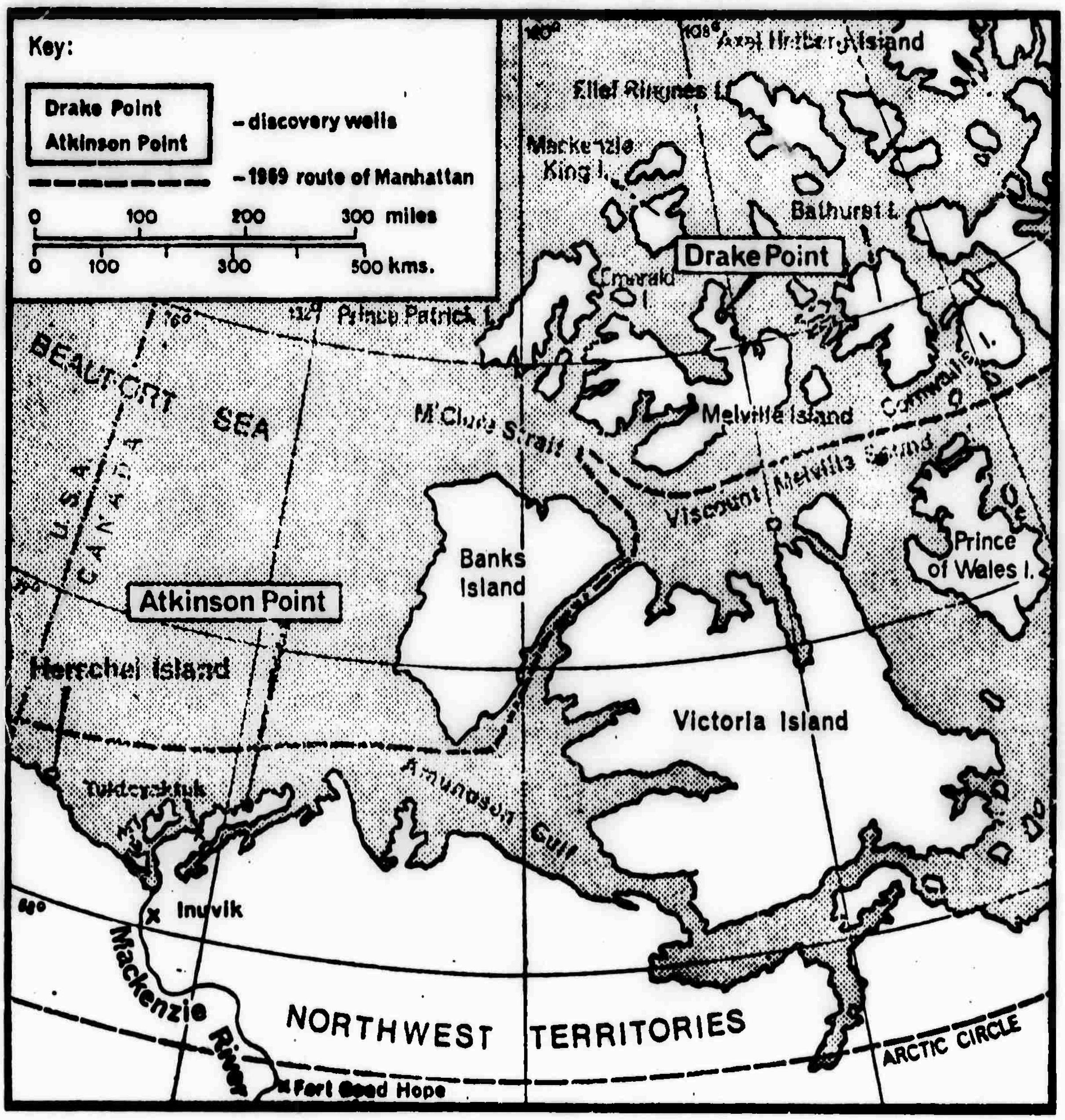
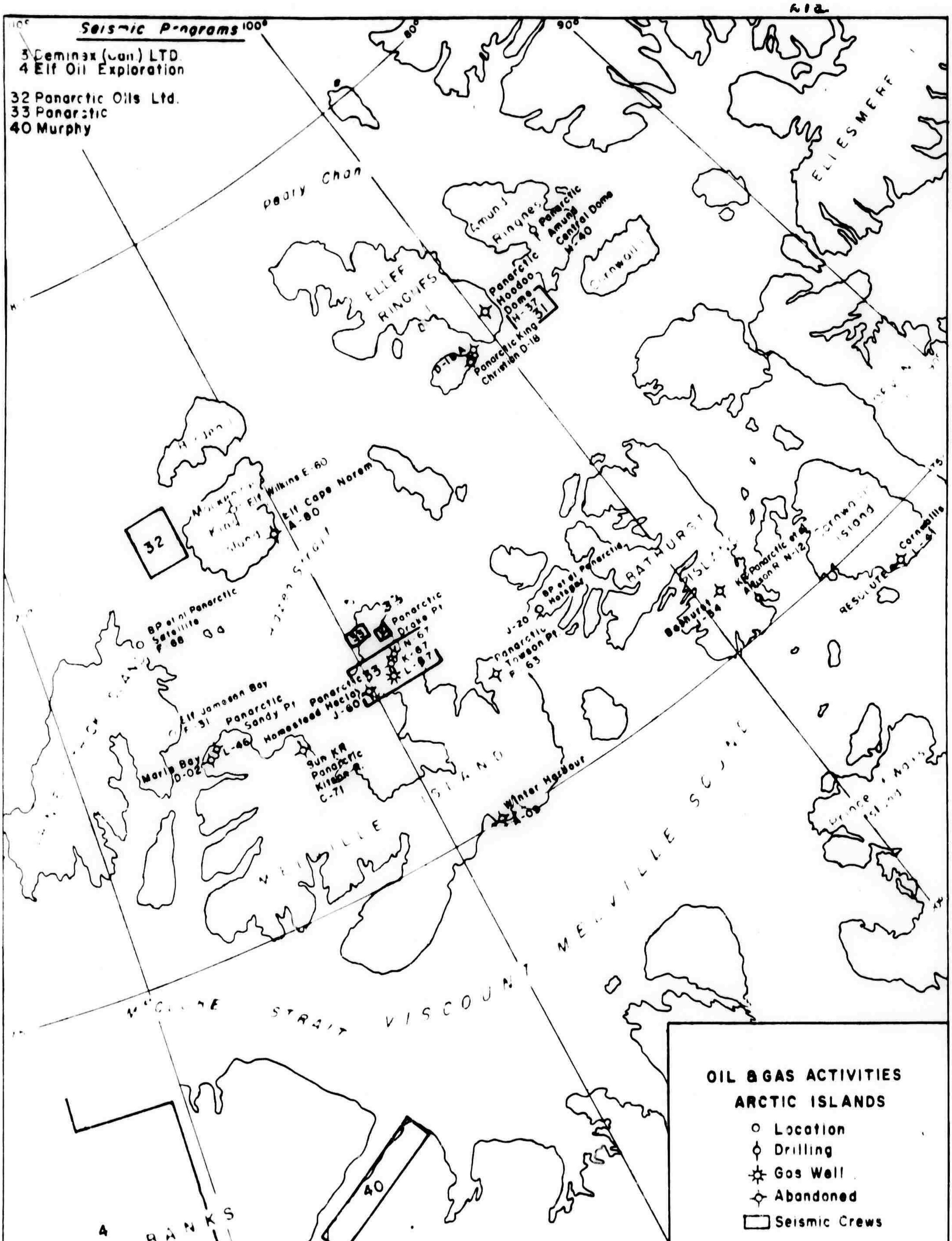


FIGURE 15 MACKENZIE DELTA AND ARCTIC ISLANDS



Seismic Programs
3 Ceminex (Can.) LTD.
4 Elf Oil Exploration
32 Panarctic Oils Ltd.
33 Panarctic
40 Murphy
OIL & GAS ACTIVITIES
ARCTIC ISLANDS
Location
Drilling
Gas Well
Abandoned
Seismic Crews
Scale : 1" = 64 Miles
Peary Chan
ELLEF RINGNES
Panarctic Amund Central Dome
Panarctic Hoodoo Dome H-37
Panarctic King Christian D-18
Elf Wilkins E-60
Elf Cape Norem A-80
BP et al Panarctic Satellite F-68
Panarctic Drake Pt
Elf Jameson Bay
Panarctic Sandy Pt
Homestead Hecla J-60
Marie Bay D-02
Sun KR Panarctic Kitson R. C-71
BP et al Panarctic Hotspur J-20
Panarctic Towson Pt F-63
BATHURST ISLAND
Bathurst
KR Panarctic et al Allison R N-12
Winter Harbour
MELVILLE ISLAND
VISCOUNT MELVILLE SOUND
STRAIT
BANKS ISLAND
ELLESMERE
RESOLUTE

Figure 16

northernmost test on Ellesmere Island. Panarctic's Fosheim N-27 is only 700 miles from the North Pole, on Fosheim Peninsula. (47) The spring of 1971 has brought on other tests by Sun Oil on Longheed, Bathurst, and Somerset Islands. Panarctic's well on King Christian Island, D-18, blew on October 25, 1970, the second devastating blowout for Panarctic. (48) Also, in 1971 a new consortium, Magnorth Petroleum Ltd., of Calgary, was formed to push exploration in the Arctic Islands. The consortium, formed by 10 Canadian and 2 U.S. firms approved a $1 million exploration budget. (49) Meanwhile, Gulf Oil Canada and Mobil Oil Canada have joined forces to explore their vast offshore areas in the Canadian Arctic. Imperial has drilled 10 more wells in the Mackenzie Delta, November 1970 - March 1971, as part of the 1971 drilling spurt. (47) The chances have been estimated as high that a major strike is imminent. In fact, an Edmonton report of a new Imperial oil strike may confirm this. More than 600 exploratory wells are predicted for drilling north of 60° during the next five years. (50)

In spite of all the activity in the way of exploration and drilling, it is still possible to give only speculative estimates of total reserves that exist in arctic Canada. However, estimates have been made by many competent private and official sources, and may provide figures that will later be more sharply refined.

First as to oil potentials above 60°: The lowest estimate in the past two years was that of the Northern Development Branch of the Department of Indian Affairs and Northern Development, which estimates 50 billion barrels. (41) That figure has been used by others who have suggested estimates in the 50-54 billion barrel range as a conservative estimate. (51)

Edgington, Campbell, and Cleland, on February 1, 1971, placed the potential oil reserves at 80-120 billion barrels in the Arctic Islands alone, plus 20-30 billion in the Mackenzie Delta. [52] In 1969 the Canadian Petroleum Association was cited as calculating the arctic reserves at 120.8 billion barrels of crude. [53] The Association added an estimate of 19.6 billion barrels of natural gas liquids, for a total of 140.4 billion barrels. [54] The highest estimates were made by the Oil and Gas Journal (U.S.) in August 1970. [55] It estimated current reserves at 53.95 billion barrels and "undiscovered potential" at 202 billion barrels, for a total of 256 billion barrels.

In summary, the recent estimates ranging from "conservative" to "undiscovered potential" range from 50 to 256 billion barrels of oil and liquid gas reserves in arctic Canada. The estimates, therefore, range from slightly more than present "proved reserves" for all of North America to a total more than five times that amount. (The estimates cited do not all give figures for recoverable oil.)

The estimates of natural gas potential from arctic Canada are equally spectacular. Roughly, estimates range from the 300 trillion cu ft figure given by the Department of Indian Affairs and Northern Development [41] to the 724.8 trillion cu ft estimates of the Canadian Petroleum Association [54] and The Oil and Gas Journal figure in August 1970 was 710 trillion cu ft. [55] The higher estimates are approximately two and a half times present proved reserves for all of North America. [53] The above figures suggest why the Department of Indian Affairs and Northern Development, which administers

Canadian oil and gas regulations, reported in late 1970 that the "permit" acreage had increased from 100 million acres to 350 million since the Prudhoe Bay discovery.

A.3.2 Metallic and Other Industrial Minerals

Table 3 shows the mineral production in arctic Canada, 1960-1969. As is indicated by the table, the small-scale minerals industry of northern Canada prior to 1964 was based largely on gold production. Together with silver it accounted for 75 percent of the value of production in Yukon and Northwest Territories.[42] In 1963 the two territories produced about equal amounts. Between the years 1964 and 1967 the value of mineral production in the NWT increased more than six-fold. In 1968 and 1969 new mines in the Yukon Territory more than doubled from 1967. The consequence was that annual production, which had been in the $30 to $35 million range before 1964, rose to $153. 2 million in 1969.[42] In 1970 nine private companies were mining metals, one company was mining asbestos, and four companies were preparaing mines for production.[42]

The Oil and Minerals Division of the Department of Indian Affairs and Northern Development concluded (1970) that, "In addition to recent large investments in new mines, confidence in the future is abundantly indicated by the tremendous expansion in exploration."[42] It pointed out that before 1964 less than 6,000 claims (o. 2 km^2) were recorded annually in the two territories. In the five years 1964-1969, five major staking rushes occurred; the Pine Point area with 27, 000 claims, Coppermine River area with 39, 000

TABLE 3 MINERAL PRODUCTION CHART, 1960 to 1969

Mineral	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969(a)	Cumulative Totals (kg)
Northwest Territories											
Gold ....$	14 194 631	14 449 028	14 974 924	14 609 250	15 586 182	17 071 580	15 990 133	14 356 476	13 28[illegible]	12 935 473	
kg	13 003	12 672	12 449	12 036	12 841	14 082	13 187	11 827	10 957	10 671	123 725
Silver ....$	70 659	73 419	84 814	107 216	91 312	1 490 754	2 325 407	3 429 755	8 677 365	3 911 170	
kg	2 472	2 422	2 264	2 409		33 116	51 694	61 585	116 673	63 024	335 659
Copper ..$	315 016	270 440	194 928	10 231		354 342	672 065	538 077	833 169	550 920	
kg	471 737	420 245	285 220	14 804		427 466	678 940	513 071	785 695	485 889	4 083 067
Nickel ...$	2 669 645	2 604 789	1 503 837								
kg	1 729 903	1 546 484	816 922								4 093 309
Lead ....$					823 279	25 677 695	31 472 562	35 665 535	33 636 984	31 037 000	
kg					2 778 523	75 144 531	95 555 249	115 556 332	113 524 822	92 988 000	495 547 547
Zinc ....$					1 111 016	28 596 474	57 128 344	60 852 900	57 504 129	67 012 000	
kg					3 556 505	85 903 051	171 612 030	190 496 033	184 992 005	199 584 000	436 143 624
Pitch-blende(d) $	9 231 698										
kg	430 884										430 884
Cadmium $						516 635	2 769 372	2 551 920	774 060		
kg						84 297	486 894	413 411	123 198		1 107 800
TOTAL . $	26 481 649	17 397 676	16 758 503	14 726 747	17 611 789	73 707 480	110 357 883	117 394 663	114 711 166	115 446 563	
Yukon Territory											
Gold ....$	2 652 004	2 371 494	2 050 255	2 084 215	2 183 611	1 698 975	1 639 103	675 725	911 338	991 700	
kg	2 429	2 079	1 704	1 717	1 799	1 400	1 352	556	751	818	14 605
Silver ....$	6 416 956	6 538 897	7 551 814	8 450 755	7 894 196	6 462 393	5 868 217	6 701 756	4 806 384	5 770 808	
kg	224 460	215 743	201 598	189 898	175 363	143 557	130 451	120 337	64 625	92 991	1 559 023
Lead ....$	2 166 638	1 712 198	1 615 980	1 867 647	2 744 235	2 766 953	2 386 684	2 141 959	970 629	4 663 120	
kg	9 202 125	7 606 788	7 389 201	7 701 496	9 261 793	8 097 754	7 246 316	6 939 948	3 275 872	13 970 880	80 692 173
Copper ..$		257 098	132 990					3 409 779	5 097 157	8 084 127	
kg		399 519	194 594					3 251 368	4 806 800	7 130 002	15 982 283
Coal ....$	97 156	114 221	115 198	123 675	98 150	85 626	46 390	15 791			
kg	6 573 843	7826 633	7 771 766	8 363 107	7 345 025	8 942 256	5 761 003	1 942 688			53 526 321
Zinc ....$	1 789 287	1 528 100	1 438 554	1 514 520	1 855 512	2 000 396	1 729 027	1 373 151	748 206	5 201 045	
kg	6 097 555	5 505 533	5 392 974	5 375 480	5 939 735	6 009 135	5 193 951	4 298 561	2 406 996	15 490 440	62 610 360
Cadmium $	206 604	228 296	231 328	326 124	428 399	386 192	306 336	265 997	147 716	243 600	
kg	65 997	64 722	61 006	61 637	59 976	63 013	53 858	43 091	23 510	31 752	528 562
Asbestos . $								406 371	8 684 125	12 701 400	
kg								2 296 273	64 612 652	89 412 400	156 321 325
TOTAL . $	13 328 645	12 750 304	13 136 119	14 366 936	15 204 103	13 400 535	11 975 757	14 990 529	21 365 555	37 655 800	

claims, Vangorda Creek-Ross River with 10,000 claims, Artillery Lake area with 8,000 claims, and Casino Creek area with 10,000 claims. The high point was reached in 1968 with 53,000 claims recorded.

A.3.2.1 Metals

Extensive iron-bearing formations are located in many northern areas of Canada. More than 139 million tons of direct-shipping ore, grading 68 percent iron or better, have been outlined in the Mary River area of north-central Baffin Island. One of the major obstacles to developing that project is the short shipping season. Immense low-grade deposits have been found also in the central Yukon. Additional sources are known on either side of the Foxe Basin. With problems of transportation, benefication (concentration), and a need for long contracts at stable prices, development of the low-grade ores may not occur for many years. They do constitute a reserve in case of future need. Considering the predicted cumulative demands for iron and steel in the U.S. alone, the anticipated demand to the year 2000 exceeds reserves by 40 percent. Canadian low-grade ore might later therefore be of strategic importance.[22]

A 3-million-ton copper deposit has been outlined in the Coppermine area of the Canadian Arctic. Further mineralization occurs between Coppermine and the Bathurst Inlet and on Victoria Island. In the Casino Creek area, west of Carmacks, recent exploration has indicated a very large low-grade copper-molybdenum deposit. Indications of porphyrycopper-type mineralization have been encountered in widely spaced localities in western Yukon Territory.[42] In April 1967, New Imperial Mines began production from an

open pit copper mine 10 miles from Whitehorse. New Imperial began exploration in 1956, and by 1965 had outlined reserves of 5. 5. million tons of ore grading 1. 2 percent, in several mineable deposits. The concentrated product - 2,000 tons per day - is being shipped to Skagway for onward transfer to Japan. (42)

Lead-zinc proved reserves in the Pine Point area exceed 40 million tons (A. Cominco, Ltd., subsidiary is the producer) with a combined zinc-lead grade of 9. 4 percent. Total capacity is 8, 000 tons per day. There are reports of another deposit in the area which is expected to grade 13 percent and contain 1. 4 million tons. More may be found. Several additional despots may be brought into production in the Anvil district (120 miles northeast). Significant high-grade deposits have also been outlined north of Resolute and Strathcona Sound in northern Baffin Island. Underground development has already begun in the 12-million-ton Strathcona Sound deposit. (42) The Anvil Mining Company development near Ross River is estimated to have reserves of 63 million tons grading 9 percent and also 31. 1 grammes of silver per ton. To obtain fuel for the concetration process the total coal output of the Tantalus Butte Mine near Carmacks produces 12, 000 tons per year.

Canada Tungsten Mining Corporation is the only tungsten producer in Canada. It operates a 300-ton-per-day mine in the Flat River area close to the Yukon - NWT boundary. The deposit in 1959 contained 1. 5 million tons, of which less than half has been mined. The Selwyn Mountain region, south-eastern Yukon Territory, contains at least one deposit in excess of one million tons, and it is considered likely that further deposits will be found. (42)

Gold and silver are found in many parts of the Canadian north and a number of high-grade gold and silver prospects are thought to exist in the Yukon. Silver is also a by-product of the Anvil lead-zinc mines, and of the New Imperial copper mines. The Mayo district near Great Bear Lake and the area west of Lake Simpson are also potential silver producers. Gold and silver do not, as of now, constitute resources of great strategic importance among the Canadian arctic minerals. Some nickel is mined east of Artillery Lake but production is minimal.

A.3.2.2 Non-Metallic Minerals

The most significant of nonmetallic minerals thus far found in arctic Canada is asbestos. The principal find is the Clinton Mine in Yukon Territory, operated by Cassiar Asbestos Corporation. The main ore body is said to contain 14 million tons of asbestos ore containing 6-7 percent fibre. An additional body of 9 million tons of lower grade ore lies to the west of the Clinton mine. Prospecting in the Yukon Territory is expected to discover additional ores. [42]

Some sulphur is to be found in the Arctic Islands. [56]

A.3.3 Other Natural Resources

Other natural resources, such as forests, fish, and game are not significant in the Canadian Arctic. Trees do not grow there and agriculture in the frozen grounds is not practical. Fish and game, though, are important to the native economy. Forests, of course, are of great importance in the

Middle North. See Figures 17 and 18.

A.3.4 Industries

A.3.4.1 General

Other than the mining and the exploitation of oil and gas, there appears to be no logical base for industrial development in the Canadian Arctic in the near future. There is no significant industry now located there. There has, however, been considerable penetration of industry into the Middle North.

A.3.4.2 Manufacturing

The high cost of shipping materials both into and out of the Arctic, the shortage of local skilled labor, the great expense of providing amenities for imported labor, the lack of communications, and other costs and climatic factors all tend to make the construction and operation of manufacturing facilities uneconomical. A small refinery at Norman Wells has been in operation for many years, but its products are used in the area and are not exported south.

In the case of metals, it is presently cheaper to ship ore concentrates and to do the refining in more temperate regions. The only industrial activity pertaining to metal production, then, will be the mining of the ores and the operation of plants to produce the desired concentrate.

In the case of oil and gas, wells will be drilled and fields developed.

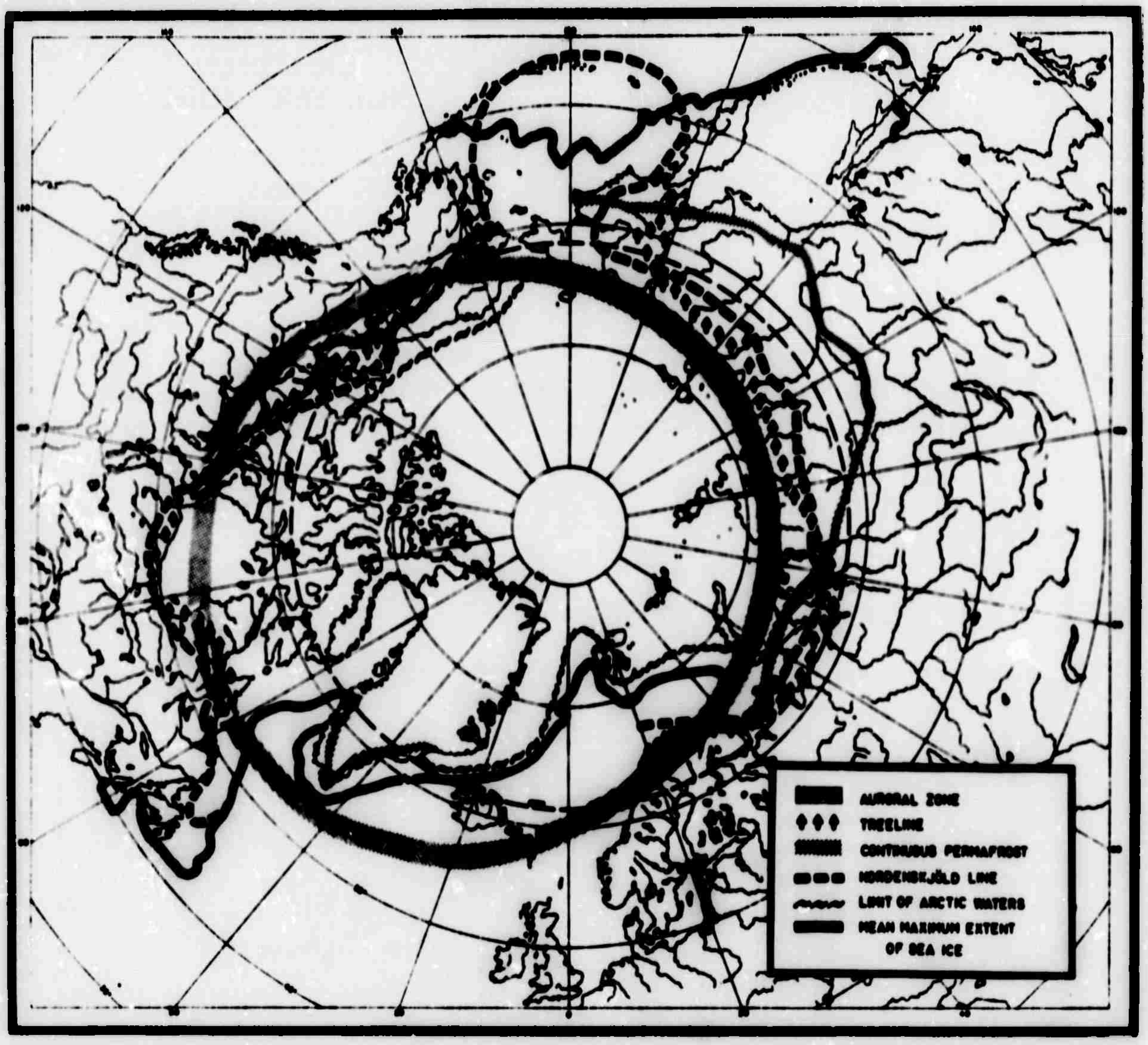


FIGURE 17 THE ARCTIC REGION

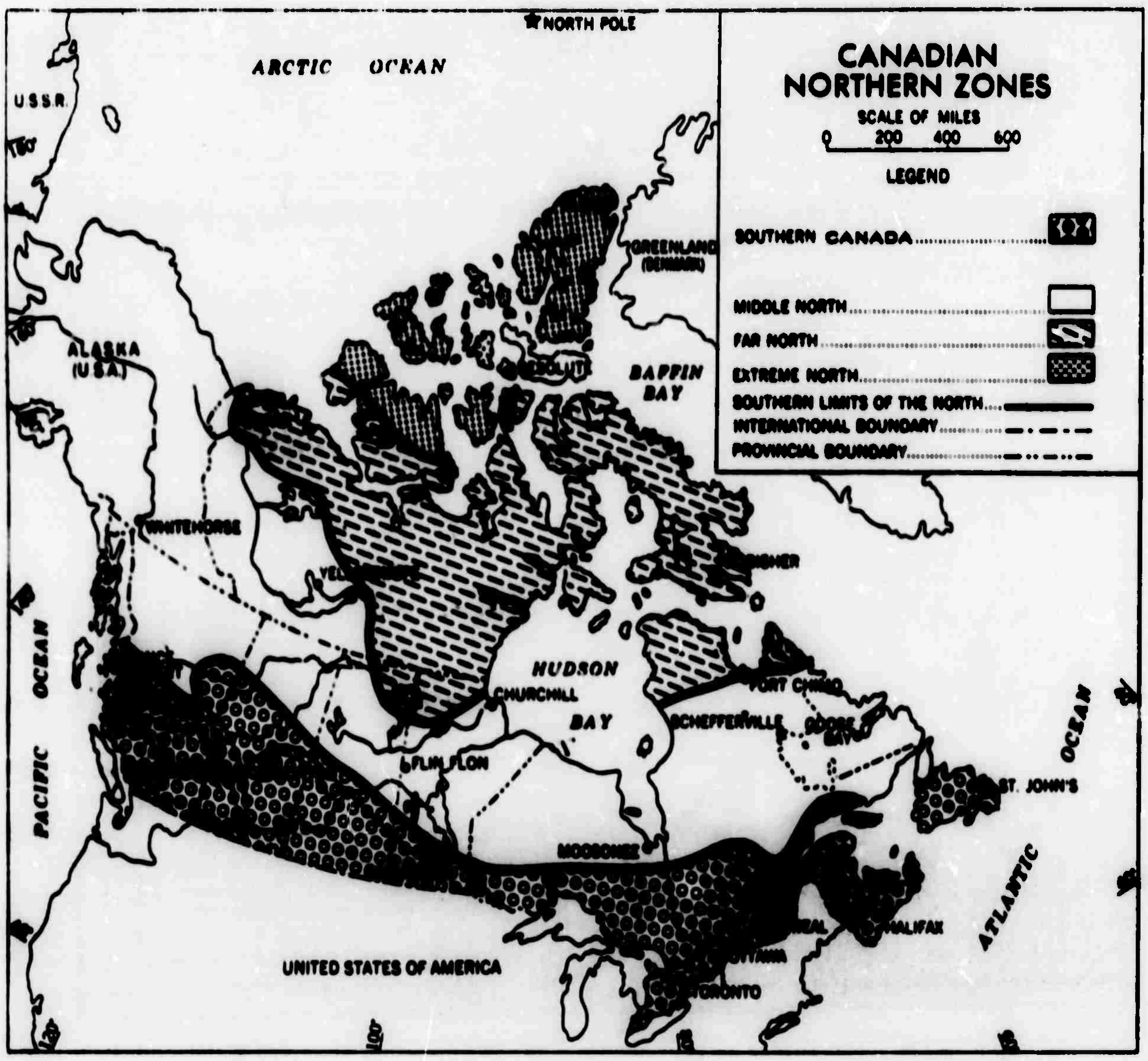


FIGURE 18 CANADIAN NORTHERN ZONES

Small refineries for producing products required locally probably will be built (such as the ARCO plant in the Prudhoe Bay area of Alaska). For gas, it may be more economical in the Arctic to operate facilities to convert it to the liquid state for shipment by sea rather than by pipeline.

Farther south, in the Middle North, is another story, For example, Thompson, Manitoba is a town that was built to serve the nickel mines of the International Nickel Company. The Company now produces about 75 million pounds of nickel a year at Thompson and the capacity is being increased to 100 million pounds a year. The town of about 10,000 people is essentially a self-run open community. The whole development was paid for by the company without government assistance. The company built and paid for a railway spur about 40 miles long from the Pas-Churchill railway line. International Nickel Company also built, owns, and operates a power plant on the Nelson River at Kettle Rapids. The town has a single purpose - the production of nickel. It is often spoken of as "sweet suburbia in the North". [57]

At Fort McMurray, in the Middle North, 230 miles northeast of Edmonton, Sun Oil Company has built a $300-million plant for the extraction of up to 45,000 barrels of high-grade crude per day from the Athabasca tar sands. [58] The Alberta government has now authorized production of 150,000 barrels per day, and several companies are competing for this development. [57]

Other developments in the Middle North could be cited. However, since they do not impact directly on operations in the Arctic Ocean, the two cited examples will suffice as illustrative of the kind of industrial developments

that have and will take place in the Middle North. Further, as the obstacles of the sub-Arctic are overcome, it can be expected that significant industrial activity will penetrate the Arctic. Nevertheless, this is unlikely to occur in the foreseeable future, certainly not through the next decade.

A.3.4.3 Other Industry

Agriculture is nonexistent in the Arctic. Commercial fishing in the Arctic is largely limited to the Arctic char, a delicacy fish which is air-shipped to luxury markets in Canada and the U.S. There are a few fish canneries.

Small service-type industries, such as repair and maintenance shops, will develop as communities are established or enlarged to accommodate personnel required in the mining and oil production. Also, there will be industrial activities associated with transportation facilities as arctic transportation systems are established.

A.3.5 Population

A.3.5.1 General

Population figures in this section are from a 1966 census. Table 4 [59], for all of Canada, gives the population of broad lateral zones (Figure 18) [59] by province or territory.

TABLE 4 POPULATION OF ZONES, BY PROVINCE OR TERRITORY, Canada, 1966

Province or Territory	Southern Canada	Middle North (essentially sub-Arctic in character)	Far and Extreme North (basically the Canadian Arctic
Newfoundland & Labrador	448,487	44,909	0
Nova Scotia	756,039	0	0
Prince Edward Is.	108,535	0	0
New Brunswick	616,788	0	0
Quebec	5,754,115	23,699	3,031
Ontario	6,945,635	15,235	0
Manitoba	902,929	60,112	25
Saskatchewan	937,251	18,093	0
Alberta	1,448,683	14,520	0
British Columbia	1,867,918	5,756	0
Northwest Territories	0	13,850	14,888
Yukon	0	14,372	10
CANADA	19,786,380	210,546	17,954

A.3.5.2 Southern Canada

In order to place the population of northern Canada in perspective, southern Canada is mentioned first. The most densely populated area of Canada lies near the Canada-U.S. border. Its major cities - Montreal, Toronto, Vancouver, Winnipeg, and Ottawa - are within 100 miles from this border. Southern Canada, i.e. the area south of the Middle North, has 19,278,380 of Canada's total population of 20,014,880. (59)

A.3.5.3 Middle North

The Middle North (essentially subarctic in character) provides the main routes of northward pioneer penetration. Its total population is 210,546 - approximately 1 percent of Canada's total population. (59) Populations of principal towns follow:

Flin Flon	11,104
Whitehorse	5,031
Yellowknife	3,241
Schefferville	3,178
Goose Bay	3,040
Churchill	1,878
Moosonee	925

A.3.5.4 Far and Extreme North

The Far and Extreme North, the zones which together form the Canadian Arctic, have a population of 17,954.[59] This is less than one-tenth of 1 percent of Canada's total population. Population figures for principal communities of the Canadian Arctic follow:

Inuvik	1,248
Cambridge Bay	531
Frobisher	512
Tuktoyaktuk	409
Coppermine	230
Resolute	153

A.3.5.5 Population Potential

It is evident from the above statistics and the large areas to which they apply that the Canadian Arctic is sparsely settled. It is likely to remain so for a very long time. Exploration and development of extractive resources alone do not stimulate large increases in population. Minerals may be reduced to concentrates in the Arctic for more economical shipment. However, refining plants in the Arctic for minerals or oil are not yet economically sound. The prospect of other manufacturing activity is even more remote. Population pressures are unlikely to force occupation of the empty arctic spaces. For the foreseeable future it is concluded that there will be only moderate population growth in the Canadian Arctic, due principally

to mineral and oil exploration and production, including ancillary service required. Population will remain scattered in small communities, rather than concentrated in a few large population centers.

A.3.6 Transportation

The Canadian Arctic stretches from Alaska to Greenland and includes the Arctic Archipelago (or Arctic Islands). From the Mackenzie Delta, the approximate southern boundary of the Canadian Arctic (the tree line) dips southeastward to encompass the southern part of the Hudson Bay and then continues eastward to the Labrador Coast (Figure 17).[60] The land area of interest that might affect surface ship operations in the Arctic includes much of the Mackenzie River Basin, the land along the rivers emptying into Hudson Bay, and the land along the Labrador Coast.

A.3.6.1 General

Of all the items that affect development in northern Canada, after climate, transportation is easily the most important. Transportation systems are minimal in the Canadian Arctic. They are somewhat better developed in the Middle North. Canada's transportation systems (excluding river transportation) are shown in Figure 19.[59] It also shows the 1969 route of the S. S. Manhattan through the Northwest Passage. Figure 20 shows the northern roads of Canada.[61] The Mackenzie River system and connecting arctic coastal routes are shown in Figure 21.[62]

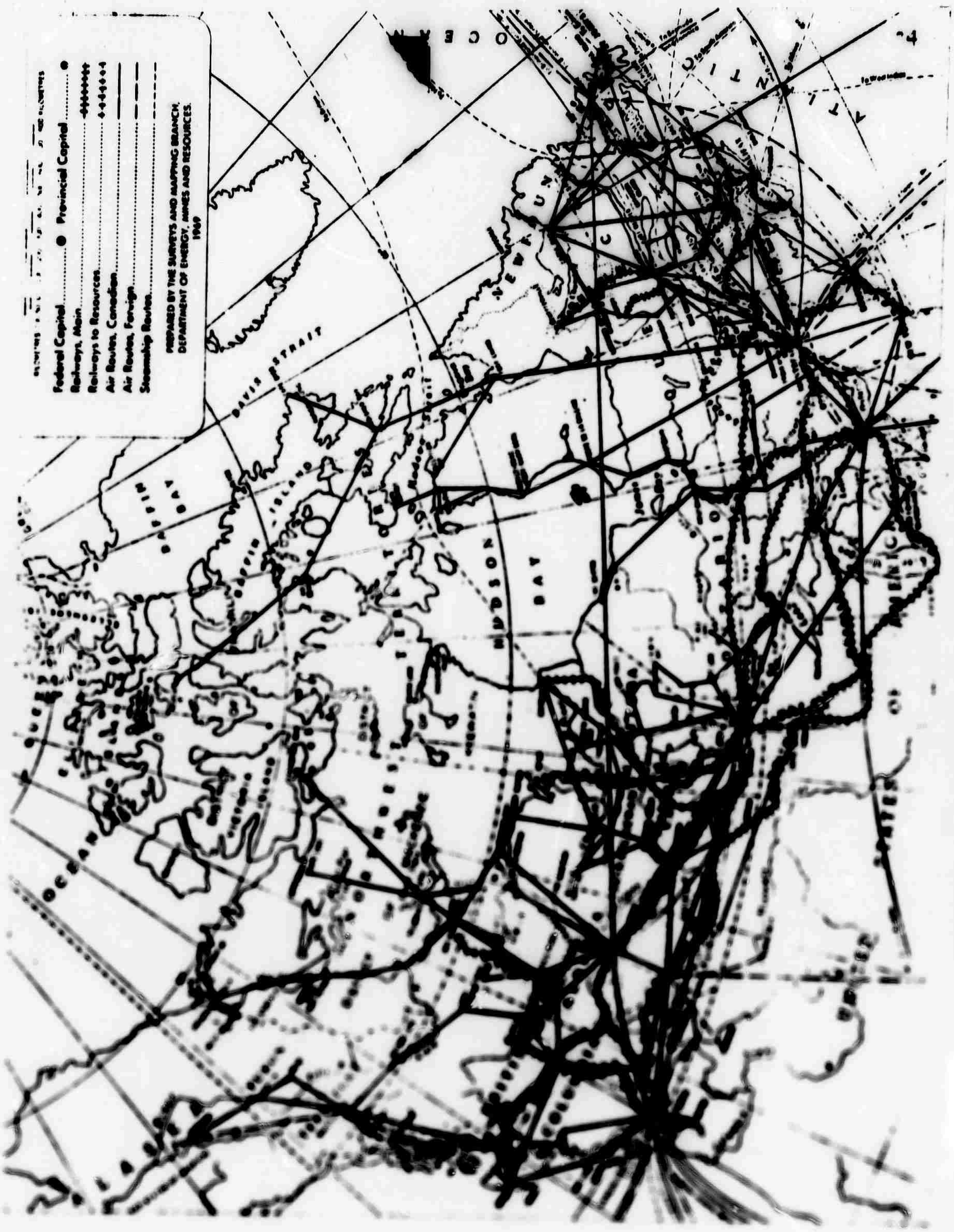


FIGURE 19 AIR ROUTES AND RAILWAYS OF CANADA

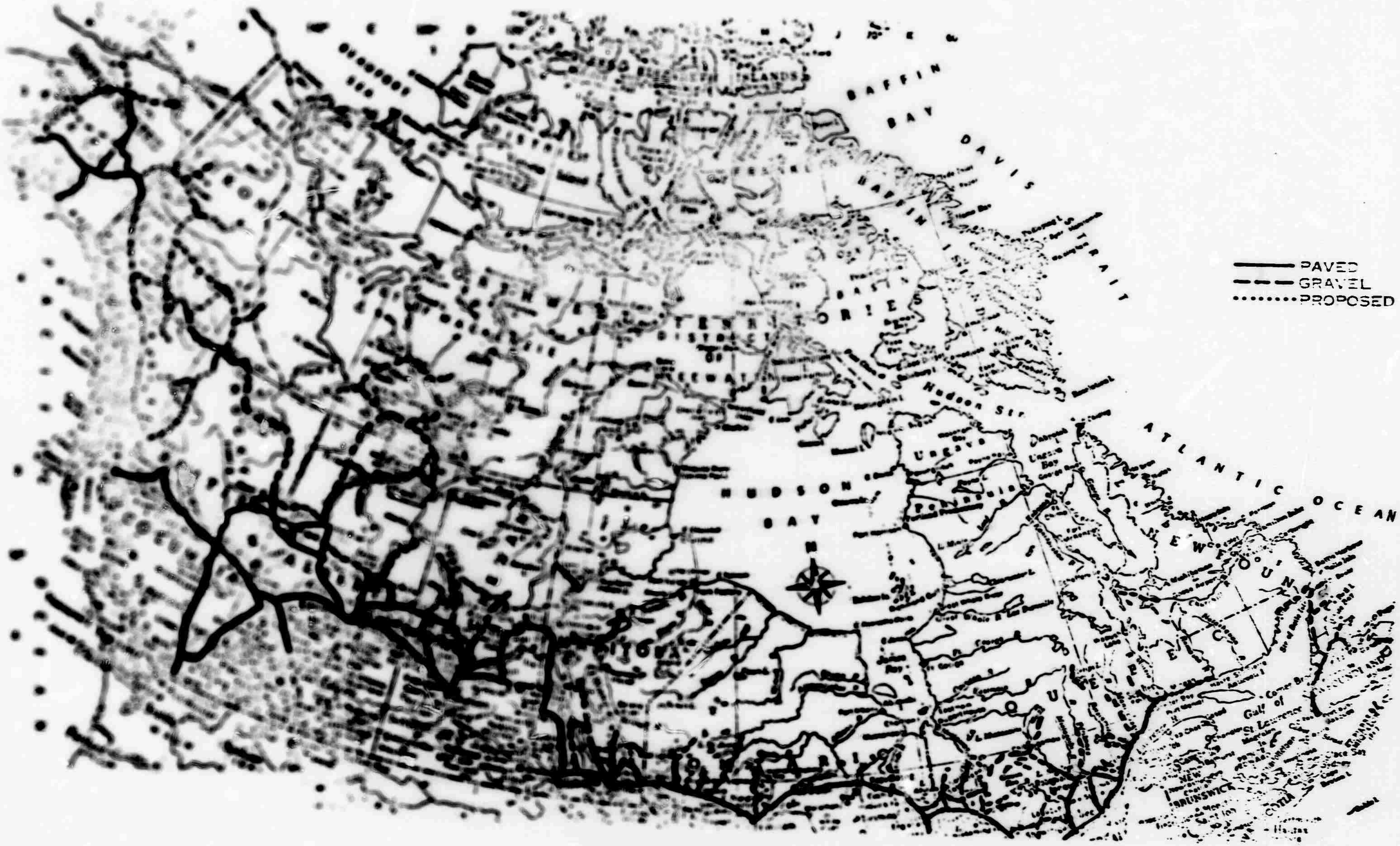


FIGURE 20 NORTHERN ROADS OF CANADA

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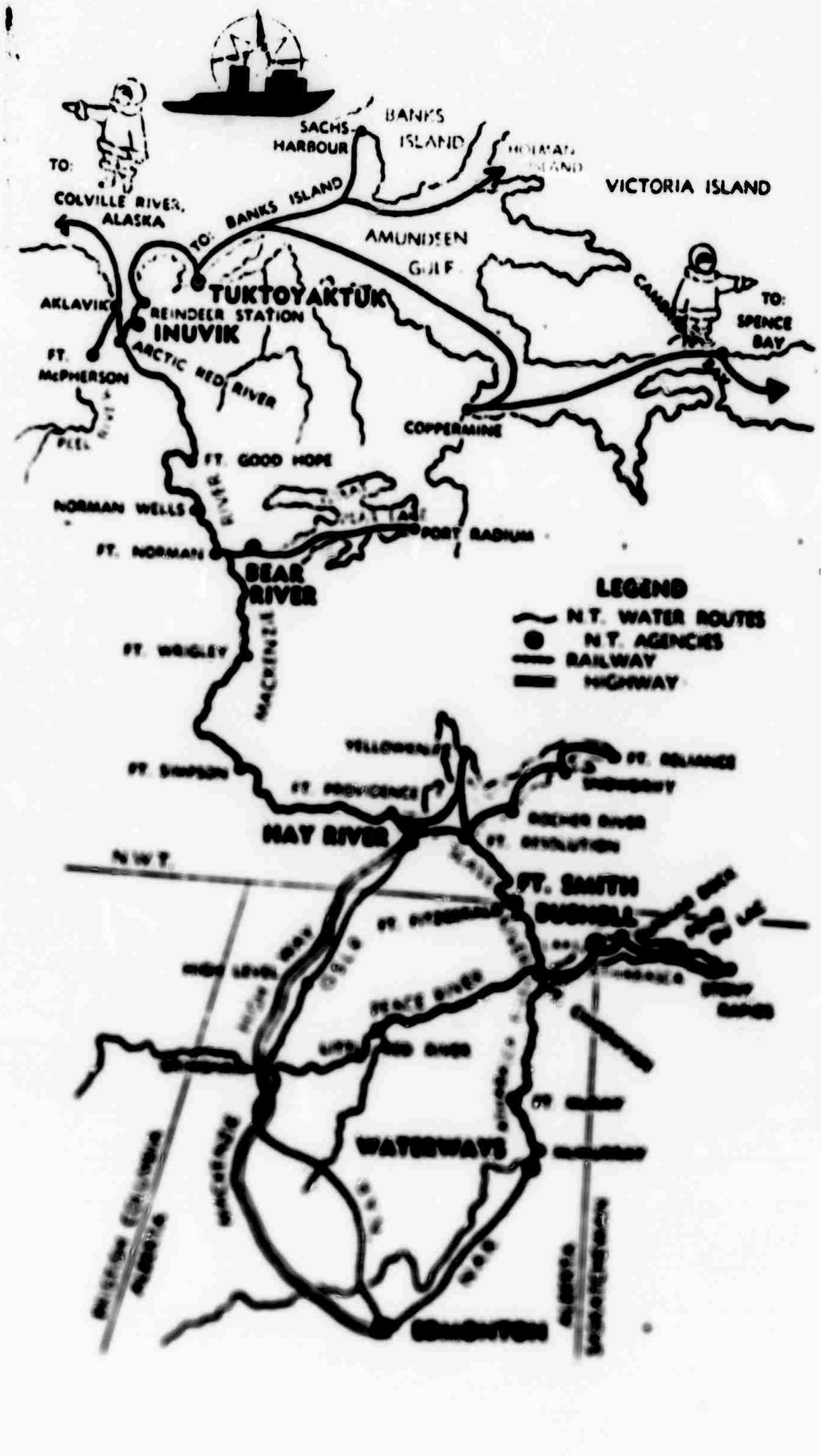


FIGURE 21 THE MACKENZIE ROUTE TO THE WESTERN ARCTIC

Considering the Canadian North as a whole, a partially integrated pattern of water, land, and air transportation operates through relatively few centers such as Whitehorse, Yukon Territory; Yellowknife, Resolute, and Frobisher Bay, Northwest Territories; Churchill, Manitoba; and Fort Chimo, Quebec. There is little east-west movement within the Arctic or Middle North. The broad pattern is the movement into the north of general and package freight and the movement out of ore concentrates. To the south, these northern routes connect with the fully integrated Canadian system of east-west highway, rail, and air routes. (57)

Special situations, such as support of the Distant Early Warning System (DEW line), the distribution of petroleum products from Norman Wells, and, more recently, the activities of the oil companies in the Arctic, have resulted in departures from the generalities stated above. (57)

The possible development of year-round arctic tanker routes to satisfy the requirements of developing Alaskan North Slope oil, as well as pipelines that may be constructed for this purpose, may have a major impact on future trends of transportation development in the Canadian Arctic.

2.3.6.2 Railroads

While no railroads extend into the Canadian Arctic, the railroads of the Middle North are worth considering. Some provide links with Arctic river and sea transportation.

The White Pass and Yukon Railway is a diesel-powered narrow-gauge railroad that operates between Whitehorse, Yukon Territory and Skagway,

Alaska. This is the main outlet for concentrates from the Yukon to the Pacific. There is concern about the ability of the railroad to handle predicted tonnages as the Yukon develops. (57)

The Great Slave Lake Railroad is operated by the Canadian National system. It connects with the main system at Roma, Alberta and extends northward to the south shore of Great Slave Lake at Hay River and thence eastward to Pine Point. Hay River is the connecting point to the water transportation system in the Mackenzie River Basin. (57) Although built principally to export lead-zinc concentrates from the Pine Point mines to to the smelter in British Columbia, this railroad has generated traffic by developments other than the mine about equal to the ore tonnage that the railroad carries. This additional traffic is made up largely of agriculture and forest products. Up to a point of northerness, there is potential growth of traffic on a rail line such as the Great Slave, but farther north there are no forests and no farms. (63)

The Northern Alberta Railway connects Edmonton and the main rail system with Waterways, from which a tug and barge service operates on the Athabasca and Slave Rivers. This railroad serves the Athabasca oil sands and also the Beaverlodge uranium mining area. (57)

A line of the Canadian National system runs from The Pas to Churchill at the edge of the Canadian Arctic on the west shore of Hudson Bay. This railroad was built principally as an outlet for wheat from the central provinces to the sea. Another railroad connects The Pas with Lynn Lake and provides a spur to Flin Flon. This is a significant mining railway. (59)

The Northern Ontario Railway connects Cochran on the main railroad network with Moosenee at the south end of James Bay, the southern extension of Hudson Bay. (57)

As the means of shipping out large tonnages of iron ore from Schefferville, Quebec, which is practically on the Labrador border, to the sea at Sept Illes, where the St. Lawrence River emerges with the Gulf of St. Lawrence, is a railroad operated by the Iron Ore Company of Canada. (57)

A railway, to be successful, has to depend on a high degree of permanence and a variety of two-way traffic. Conditions in the Canadian Arctic are not yet conducive to railways from this point of view. (63) No plans are now known for extension of railways into the Canadian Arctic.

Canadian railways as a whole loaded 186 million tons of unduplicated freight in 1967, and carried each ton an average distance of 447 miles. Freight traffic in terms of ton - miles was over 94,000 million. (59)

A.3.6.3 Highways

There are no highways in the Canadian north, except gravel roads in the subarctic areas of western Canada. The Alaska Highway connects with the integrated highway system farther south at Dawson Creek, British Columbia and runs west and north through Whitehorse, Yukon Territory to the Alaska border at the 141st meridian near the head of the Tanana River and on down the Tanana Valley to Fairbanks, Alaska. In Canada, it is a well-maintained full-width gravel road. (57)

From Haines Junction, west of Whitehorse, the Haines cut off runs

southward across a narrow extent of British Columbia to Haines, Alaska, not far from Skagway. Also from the Alaska Highway, branch roads spread widely to points in the Yukon and British Columbia. Most of these give access to mining areas. (57)

The Klondike Highway runs northward from Carcross through White-horse and Carmacks to Dawson. From there a road runs westward to connect with the Alaska Highway system. The Dempster Highway is being pushed northward toward Fort McPherson. Roads also run from Johnsons Crossing and from Watson Lake to Ross River. Another road has been extended west to near Carmacks to serve the Anvil Creek mining area. (57)

The Mackenzie Highway, maintained to a standard comparable to that of the Alaska Highway, generally parallels the Great Slave Lake Railway but extends much farther. It runs eastward and southward from Hay River to Pine Point and Fort Smith and northward to Yellowknife, Northwest Territories. A branch is being pushed down the Mackenzie River to Fort Simpson. These roads aid mineral developments. (57)

Within the next decade, roads can be expected to penetrate to the arctic coast. For instance, there has been some talk of an all-season road from Yellowknife to Coppermine. (61) The increased tempo of exploration activity along the Arctic coast may lead, at least, to winter roads, as in Alaska.

A.3.6.4 Transportation

The Mackenzie watershed (see Figure 21) is the one major water systems used for navigation in the development of the vast area of northwestern Canada. It is the only inland water route extending through to the North American Artic and is the main navigation route for movement of freight into the western Canadian Arctic. It has been used for moving oil rigs and supplies to the North Slope area

of Alaska since 1963. (64)

The Mackenzie with its tributary rivers and lakes totals 3,274 miles of navigable channels. For purposes of comparison, the Mississippi River system with its principal tributaries, i.e. the Missouri, Ohio, and Illinois waterways, totals 3,866 miles, not a great deal more than the Mackenzie.

Essentially, the only transportation system operator using the Mackenzie watershed is the Northern Transportation Company, Ltd., a Crown Corportation. The company operates barges and tugs from the road and rail head at Hay River and other points throughout the Mackenzie River system. It operates a service along the arctic coast from Tuktoyaktuk at the mouth of the Mackenzie. It serves the arctic coast (Canada and Alaska) from 95° to 150° W and the Arctic Islands to 72° N. Tuktoyaktuk has a governing depth of 13 feet and is usually open from mid-July to early October. (60) Operations are seasonal. The open season for the Mackenzie system and adjacent coastal waters normally extends from two to five months, generally decreasing as the more northerly areas are reached. (60) (64) The Canadian Government provides one icebreaker to support the coastal operations. 260,000 tons of cargo were shipped down the Mackenzie in 1969, with 10 percent of that to the North Slope.

For comparative purposes, the freight tonnages handled at the 12 major ports in Canada are shown in Table 5. (59) It is apparent that tonnages now handled in the western Canadian Arctic are minor compared to those in Canada as a whole. It is noted that the port of Sept Illes, whose tonnage includes the iron ore from northern Quebec, ranks second in tonnage

TABLE 5 THE TWELVE MAJOR PORTS OF CANADA, 1967

Port	Total Freight Handled (million tons)	Foreign as % of Foreign & Coastwise	Loaded as % of Loaded and Unloaded
Vancouver, B.C.	24.1	56	72
Sept-Iles/Pointe Noire, Que.	22.6	85	96
Montreal, Que.	18.5	54	45
Port Arthur & Fort William, Ont.	15.3	28	91
Hamilton, Ont.	10.0	65	6
Port Cartier, Que.	9.5	98	97
Halifax, N.S.	9.0	72	46
Quebec, Que.	7.0	51	33
Toronto, Ont.	5.8	64	9
Saint John, N.B.	5.6	75	39
New Westminster, B.C.	5.3	30	68
Sault Ste. Marie, Ont.	4.5	69	9
All Ports	238.2	55	57

handled in Canadian ports.

In the eastern arctic of Canada many ships each year operate over a number of routes to many localities. An important segment of marine transport is the shipment of grain from the central provinces to Europe from the railroad at Churchill, Manitoba through Hudson Bay and Hudson Strait. (57) Ordinary freighters for many years have been able to reach the port of Churchill in summer (from mid-July to late October). Churchill has a 30- to 32-foot water depth alongside the docks and a 28-foot depth in the approach channel. (60)

Canada's Department of Transport, in effect, runs a commercial shipping company. (45) It uses naval supply ships, chartered motor vessels and larger ships, and several icebreakers. 1966 records show approximately 100,000 tons of shipping to the eastern arctic handled by the Department of Transport. (57)

Some of the ports served in the Canadian Arctic by seasonal shipping are Resolute, Eureka (on Ellesmere Island), Frobisher, and small settlements on the periphery of Hudson Bay and Ungava Bay, e.g. Fort Chimo.

The government of Manitoba has initiated rail-water transportation to Europe from Churchill and is considering other possible harbor sites on the west shore of Hudson Bay. The purpose is export of both minerals and forest products from northern Manitoba and possibly the Keewatin district of the Northwest Territories (in eastern Canada).

Research on transportation of solids by pipeline is being carried out in Canada. The economics of solids pipelines are understood, and the

technology is not too difficult. The problem of keeping outside pipelines from freezing in extreme climates may prove to be the decisive factor in preventing their use in the North. [65]

A.3.4.5 Off-Road Vehicle Transportation

Off-road vehicle transportation is important in arctic areas. A variety of low-ground-pressure vehicles are used. For hauling heavy freight over virgin land, the most common solution has been the tractor-hauled sled train. Given the need for repeated hauls, a winter road of compacted snow may be built, such as the one in Alaska to the North Slope oil fields. Summer thaw, however, makes the tundra terrain virtually impassable.

Surface-effect vehicles (SEV or ACV) may play a significant role in development of surface transportation in the Canadian Arctic. [66] As yet that type of vehicle does not have a sufficiently favorable payload-fuel-distance relationship to make it commercially competitive with other forms of transportation. For special purposes, however, it may be useful.

The exploration phase of mineral development (including oil and gas) in the Canadian Arctic is increasing demands for off-road transportation. Tonnage figures are not available.

A.3.4.6 Air Transportation

The Canadian air transportation net for scheduled air lines is shown in Figure 19. The principal arctic centers provided with regular service

are Inuvik, Tuktoyaktuk, Coppermine, Cambridge Bay, Resolute, Churchill, and Frobisher. There is a well-developed network in the Middle North and southern Canada. In addition to scheduled air service, there are a number of small companies and charter operators who fly to any place that has business activity and the facilities to handle aircraft.[57] The operations of Canadian air carriers for 1966 and 1967 are shown in Table 6.[44] Foreign air carriers serving points in Canada are not included.

Except during the short ice-free open-navigation season, air transport is the key to getting around in the barrens and throughout the Arctic Archipelago.[57]

New high-capacity cargo aircraft may have an increasing role. A generalized study by the Arctic Institute of North America showed that seasonal sea transport of 30,000 tons per year of copper concentrates from Coppermine to Tokyo might cost $16 per ton, including stockpiling, whereas a C-5 type aircraft might do the job for $71 per ton. The gap is not as large as might be expected.[57]

As in Alaska, complete oil rigs can be flown into the Arctic by C-130 and premium transportation of that type is used to avoid delays due to seasonal shipping.

4.3.6.7. Sea Transportation

The possibility of year-round, or nearly year-round, sea transportation has been discussed in connection with development of Alaskan North Slope petroleum history, and the advantages of an all-year-round tanker service

TABLE 6 OPERATIONS OF CANADIAN AIR CARRIERS, 1966 AND 1967

	Scheduled Carriers 1967	Non-Scheduled Carriers 1967	Total 1967	Total 1966
Operating Revenues ($ millions)	475.1	108.5	583.6	460.4
Passengers (unit toll)	353.4	0.6	354.0	331.2
Goods (unit toll)	81.3	43.9	125.2	129.4
Charter and Contract	31.9	45.7	77.6	58.7
Specialty and Non-Flying Services	6.1	15.2	21.4	17.4
Net Income after Taxes ($ millions)	6.2	4.9	11.1	15.7
Revenue Traffic Carried				
Passengers (millions)	6.1	0.8	6.9	7.5
Goods (lb., millions)	252.2	114.7	366.9	357.3

are obvious, particularly in the face of pipeline difficulties and costs.

An advantage to Canada in opening a year-round Northwest Passage is the favorable impact it would have on mineral development. Surely, for example, the Mary River iron ore in Baffin Island would be exploited. Even nearly year-round sea transportation would permit exploitation of many minerals that cannot now be economically produced and shipped.

If the Northwest Passage is chosen as the route and routes north of the Arctic Islands are not developed, Canadian government policy can affect the competitive position of Alaskan crude. This can be done through levy of user charges for the indirect costs of aids to navigation and through enforcement of the recently enacted Canadian laws and regulations concerned with oil pollution in this area.

The Canada Act to Avert Oil Pollution Disasters in Arctic Waters establishes authority to inspect shipping and to control any resulting pollution within a line running from the Yukon-Alaska boundary around the Arctic Archipelago at a distance of approximately 100 miles and thence down Baffin Bay to 60° N latitude, halfway between Canada and Greenland. Among other things, the Act gives powers of inspection and allows for the application of government standards to all construction work in the area and to incoming shipping.

Cost comparisons that have been made between tanker and pipeline delivery to the east coast of the United States vary considerably. Generally, they show tanker delivery to be significantly cheaper. It is believed that the ultimate decision as to whether or not to use tankers for exporting oil from the North Slope and Canadian Arctic to the east coast of the United States

and Canada and/or directly to Europe will depend on economic factors. It appears to be technologically impossible.

3.3.4.4 Pipelines

The discussion of pipeline projects and proposals to move oil/gas from northern Alaska has indicated that there is much interest in Canada in the possible construction of such pipelines up the Mackenzie Valley, either originating in Alaska, or perhaps tapping only Canadian oil and gas. Planning, research and corporate activity has reached the point where it was reported in January 1971 that an expenditure of $350 million by five company groups is contemplated for 1971. (67)

The four principal planning groups were Interprovincial Pipeline, Trans-Alaska, Alberta Gas Trunk Line Company, and Mountain Pacific Pipeline, Ltd.

Interprovincial was one of the original partners in the Mackenzie Valley Pipeline Research Company, Limited. It was the first group to study the feasibility of a crude oil line from Prudhoe Bay to Edmonton. The plan would envisage that from Edmonton some oil would be transmitted via Interprovincial to Midwestern U.S. and some by Trans-Mountain to West Coast refineries. (67)

Trans-Canada heads a six-company study group which is spending $12 million to study the feasibility of a northern Alaska - central Canada - midwest U.S. gas pipeline. The projected line would be 2,500 miles long, of 48-inch pipe. The estimated cost would be $2.5 billion. Trans-Canada already has

453 miles of 36-inch pipeline and 230 miles of 42-inch gas pipeline. Several U.S. companies are among the partners, including ARCO, Humble and Sohio. (82)

Alberta Gas Trunk Line Company, Limited reportedly plans to spend $200 million on a study of a gas pipeline from Prudhoe Bay to the Alberta-Northwest Territories border. Texas Eastern Transmission and Columbia Gas are affiliated in the venture. (Columbia Gas recently bought some North Slope rights from Sohio.)

Mountain Pacific Pipeline, Limited is a fourth proposed pipeline system to bring gas from Alaska and northern Canada. It is reported to have proposed a 1,100 mile, 48-inch pipeline to Fort Laird, Northwest Territories, where the line would split, one to western U.S. and Canada and the other to central Canada and the U.S. The total cost estimate was given as $1.6 million.

It should be recalled that the Canadian Government has issued guidelines, made public by Minister of Energy, J.J. Greene, and Minister of Indian Affairs and North Development, Jean Crétien, concerning Canadian ownership and participation in oil and gas pipelines from the Canadian North. It has been specified that no more than one pipeline corridor from the North would be licensed. Hence there is competition among the several pipeline planning groups.

Thus far much of the planning has involved Alaskan oil and gas. If and when proved sizeable reserves of oil/gas in the Mackenzie Delta region are outlined, the attention would also shift more to recoveries from that area. As yet no plans have been announced for pipelines as a method of tapping

possible oil/gas finds in the Sverdrup Basin and in other remote areas in the Arctic Islands. However, a group called The Gas Arctic Systems Study Group has commissioned a preliminary assessment of the feasibility of transporting natural gas from Canada's Arctic Islands.(64) The group has assigned Pipeline Engineering and Management Services of Canada to study all possible means of moving to market the gas reserves in the Islands, where Panarctic Oils has already made two significant discoveries. Among the alternatives to be studied are a pipeline from the discovery areas on Melville and King Christian Islands to the western Canadian arctic mainland, and a pipeline running southward along the Boothia Peninsula and the western shore of Hudson Bay. A line angling to the west would link with Gas Arctic's proposed line from Prudhoe Bay, Alaska, to the Grande Prairie area of Alberta. The Boothia line would connect with existing gas pipeline systems in the Great Lakes area of Canada and the United States.

A.4 U.S.S.R. ARCTIC RESOURCES

A.4.1 Energy Resources

The trends of the U.S.S.R. fuel production are shown in Table 7.[69] It shows the comparative importance of different fuels by reducing them to standard fuel units. The increase in relative importance of petroleum in the 1950's and 1960's was due mainly to the expansion of the Volga-Urals oil production. Natural gas became significant only after 1955, with the discovery of large gas fields and the completion of pipelines. The relative significance of coal production has been declining steadily since 1950.

Table 7 Fuel Structure of the U.S.S.R. (in percent)

	1940	1945	1950	1955	1960	1965
Petroleum	18.7	15.0	17.4	21.1	30.5	35.9
Natural Gas	1.9	2.3	2.3	2.4	7.9	15.6
Coal	59.1	62.2	66.1	64.8	53.9	42.9
Peat	5.7	4.9	4.8	4.3	2.9	1.7
Oil Shale	0.3	0.2	0.4	0.7	0.7	0.8
Firewood	14.3	15.4	9.0	6.7	4.1	3.1

A.4.1.1 Coal

Figure 22 shows the principal U.S.S.R. coal basins.[69] Total production has increased from 165.9 million metric tons in 1940 to 577.7 million in 1965. The Pechora Basin production in the arctic region, despite its large reserves, has been only about 10 million tons since 1958. Its production

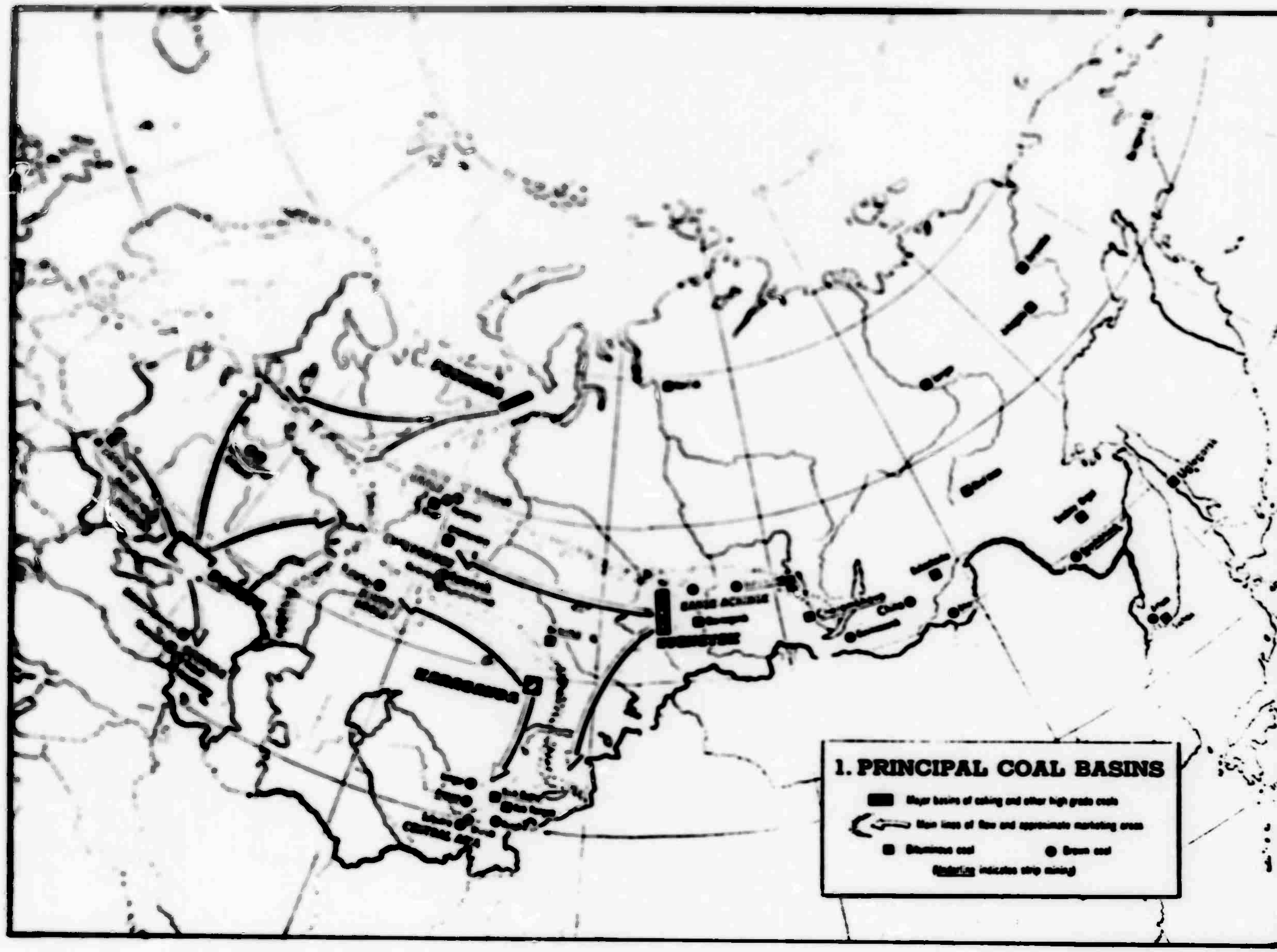


FIGURE 22 PRINCIPAL COAL BASINS

has been limited by high mining costs due to adverse climatic and working conditions. The limited coal mining at other arctic locations of Norelsk, Sanger, Arkagala, and Zyryanka have been primarily for local use.

The increased importance of oil and gas production in the U.S.S.R. since 1955 has reduced the relative importance of the coal mining industry. This trend is likely to continue. In 1956, Soviet geologists claimed that their country possessed 55 percent of the world's coal supply. [70] Of those estimates, 85 percent consisted of "possible reserves" in the little known basins of northern Sibera. The Pechora Basin deposits are estimated at 303 billion tons. [71] Taymyr Basin at 583.5 billion; Yenisey District at 221.7 billion; and the Lena Basin at 2,647.0 billion. Total U.S.S.R. mineable coal reserves are estimated at 7.7 trillion tons. [70] Although the U.S.S.R. arctic coal reserves are enormous, it is unlikely that they will be worked extensively, except perhaps the Pechora Basin reserve, because of high production costs and the competitive advantages of oil and gas.

A.4.1.2 Electric Power

The total generating capacity of the U.S.S.R. has risen sharply since 1955, from 37 million kilowatts to 115 million in 1965. Most of the generating capacity is south of the arctic area. [69] (See Figure 23).

The Kola Peninsula depends largely on hydroelectric power for its industrial energy. Hydroelectric stations generated about 70 percent of the total electricity output of 6 billion kilowatt-hours in the mid-1960's. [69]

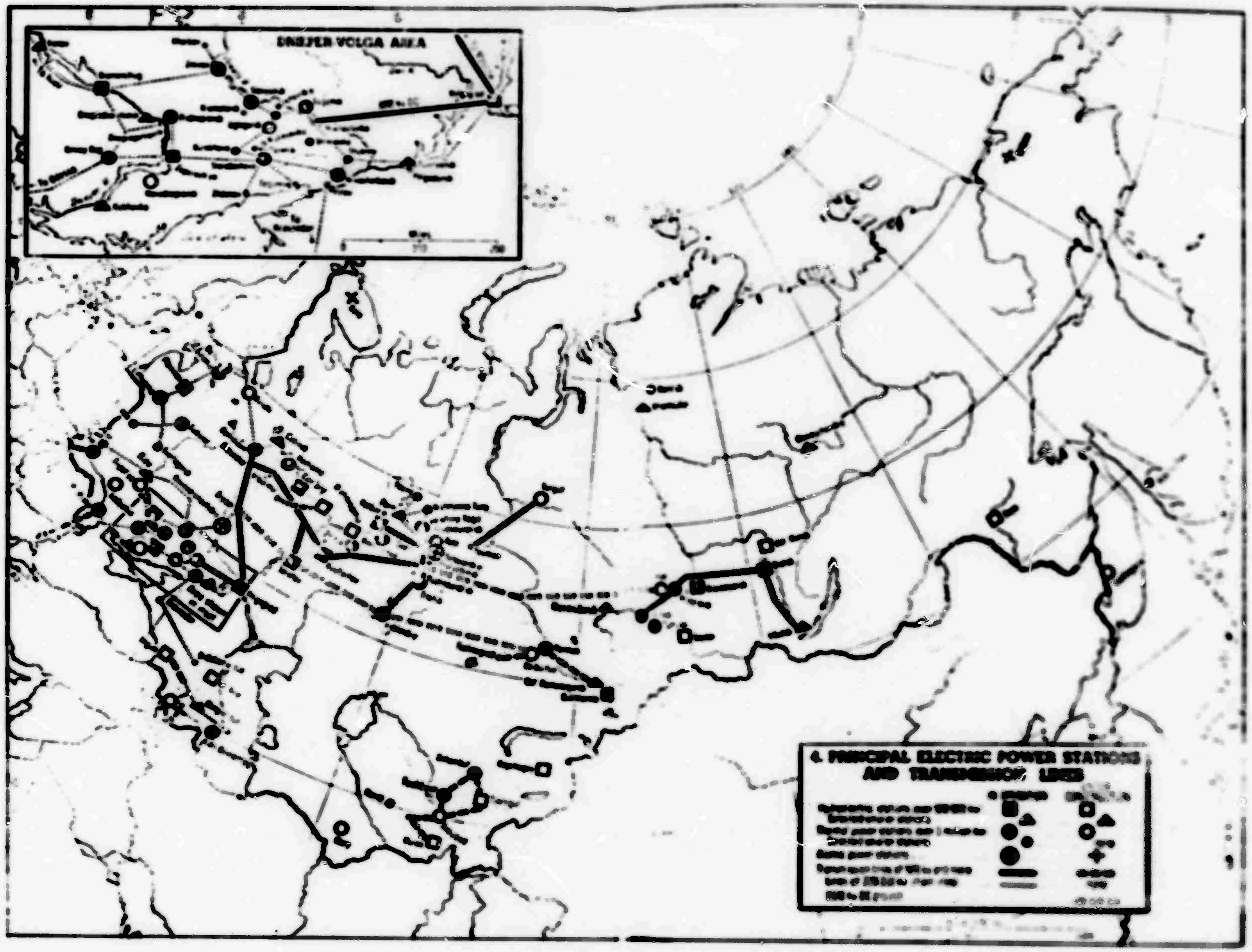


FIGURE 23 PRINCIPAL ELECTRIC POWER STATIONS AND TRANSMISSION LINES

Principal power systems are on the Niva, Tuloma, and Pas Rivers. The peninsula has been selected for one of the 800,000-kilowatt central nuclear power stations of the pressurized water type. The station, under construction south of Murmansk, will help raise the electrical generating capacity of the Kola Peninsula from about 1.5 million kilowatts in the late 1960's to 2.5 million kilowatts sometime in the 1970's. A small 400-kilowatt tidal power test installation was completed in 1968 at Kislaya Guba. There are plans for a 320,000-kilowatt tidal station at Lumbovka Bay, on the north shore of the Kola Peninsula, 200 miles southeast of Murmansk.

Around the White Sea area, the power stations are hydroelectric. Power stations include the Vyg River system with a capacity of 230,000 kilowatts, the Kem River system with a capacity of 250,000 kilowatts, and the Kovda-Kuma system with a total capacity of 300,000 kilowatts. [69] There are plans for a tidal power station at the mouth of the Mezen River. [69]

Electric power output in the Pechora Basin has been limited to heat and power stations at Vorkuta burning coal. Plans have been made for the construction of a 1.5 million kilowatt hydroelectric station at Ust'-Izhma, on the Pechora River at the mouth of the Izhma, a left tributary. [69] The feasible power resources from the Pechora, Vychegda, and Mezen rivers are estimated at 22 billion kilowatt hours during a year of average water flow.

The arctic region of Western Siberia has had little power development. There were plans for a 6- to 7- million kilowatt hydroelectric station on the Lower Ob just above Salekhard. However, this has been opposed because its vast lowland reservoir would flood future valuable farmlands, interfere with the development of other resources (such as oil, gas, and timber), and cause adverse effects in the regional water balance, climate, and soils. [69] Norilsk has a coal thermal electric station with a capacity of

300,000 kilowatts or more. This is to be supplemented in 1972 by the 441,000-kilowatt hydroelectric station on the Khantayka River - - one of the Soviet Union's northernmost hydroelectric plants.

Aykhal, in Central Siberia, as part of the diamond industry, is served by a 312,000-kilowatt hydroelectric station on the Vilyuy River at Chernyshevskiy. Further east, a 17,000-kilowatt thermoelectric power station exists at Pevek using coal brought in by ship.(69) A floating 20,000-kilowatt power station moored at Zeleny Mys burns coal from a deposit upstream on the Kolyma River. Four atomic power plants with a capacity of 12,000 - kilowatts each are planned at Bilibino. A 12,000-kilowatt power station near Egvekinot serves the Iul'tin mining district burning coal from nearby seaboard coal mines.

3.4.1.3 Oil and Gas

Figures 24 & 25 show principal oil fields and pipelines.

Total U.S.S.R. production has been increasing since 1945 at a rate which now places the U.S.S.R. in second place among the world oil producers. (69) (72)

Table 8 - U.S.S.R. Oil Production (in million metric tons)

1945	1950	1955	1960	1965	1970
19.5	37.9	70.8	147.9	242.9	353.0

Recently disclosed targets for 1975 are as high as 480 to 500 million metric tons, an increase from 1970 of nearly 50 percent. Refinery capacity and output is to be correspondingly increased. (72)

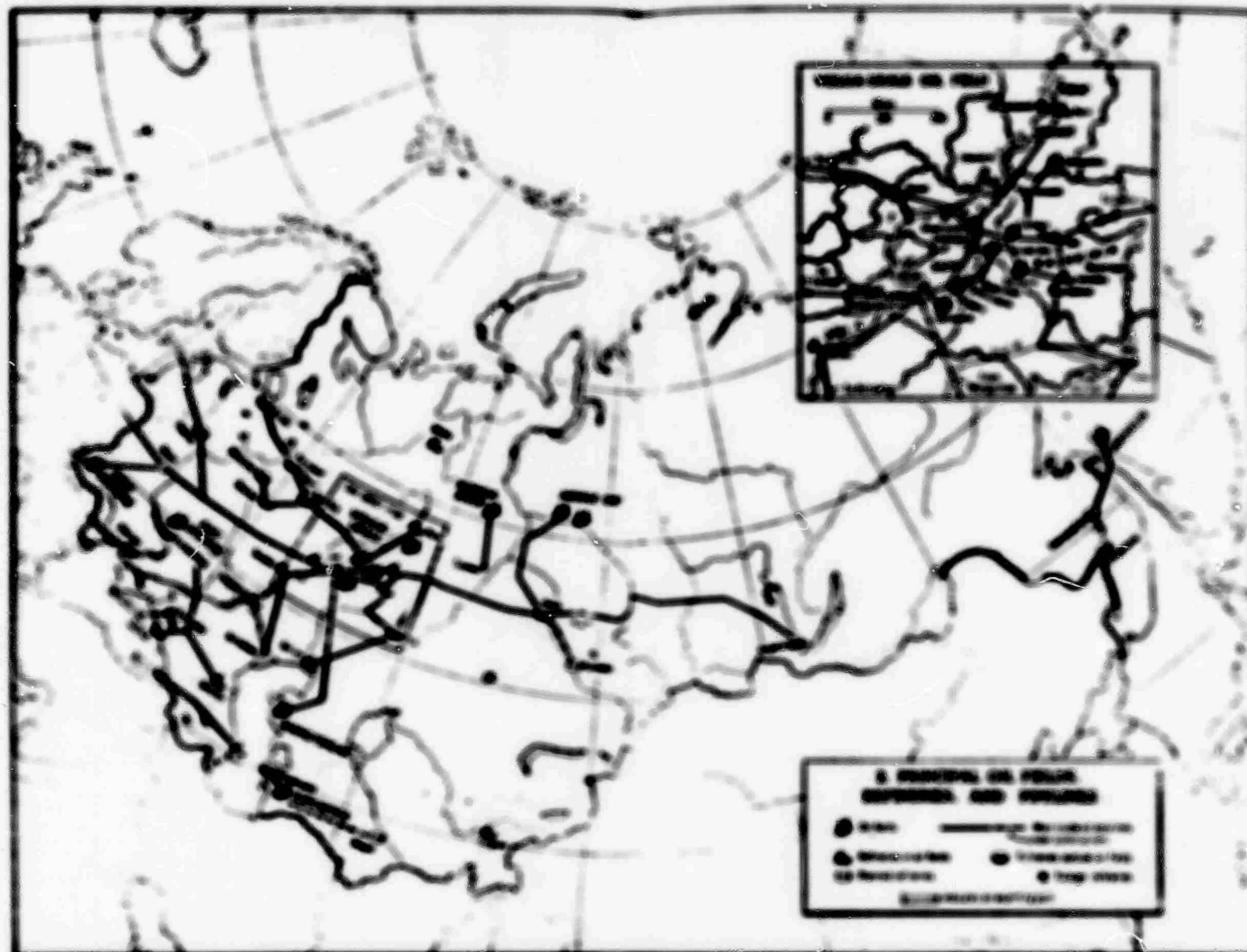


FIGURE 24 PRINCIPAL OIL FIELDS, REFINERIES, AND PIPELINES

OIL INDUSTRY IN THE SOVIET UNION

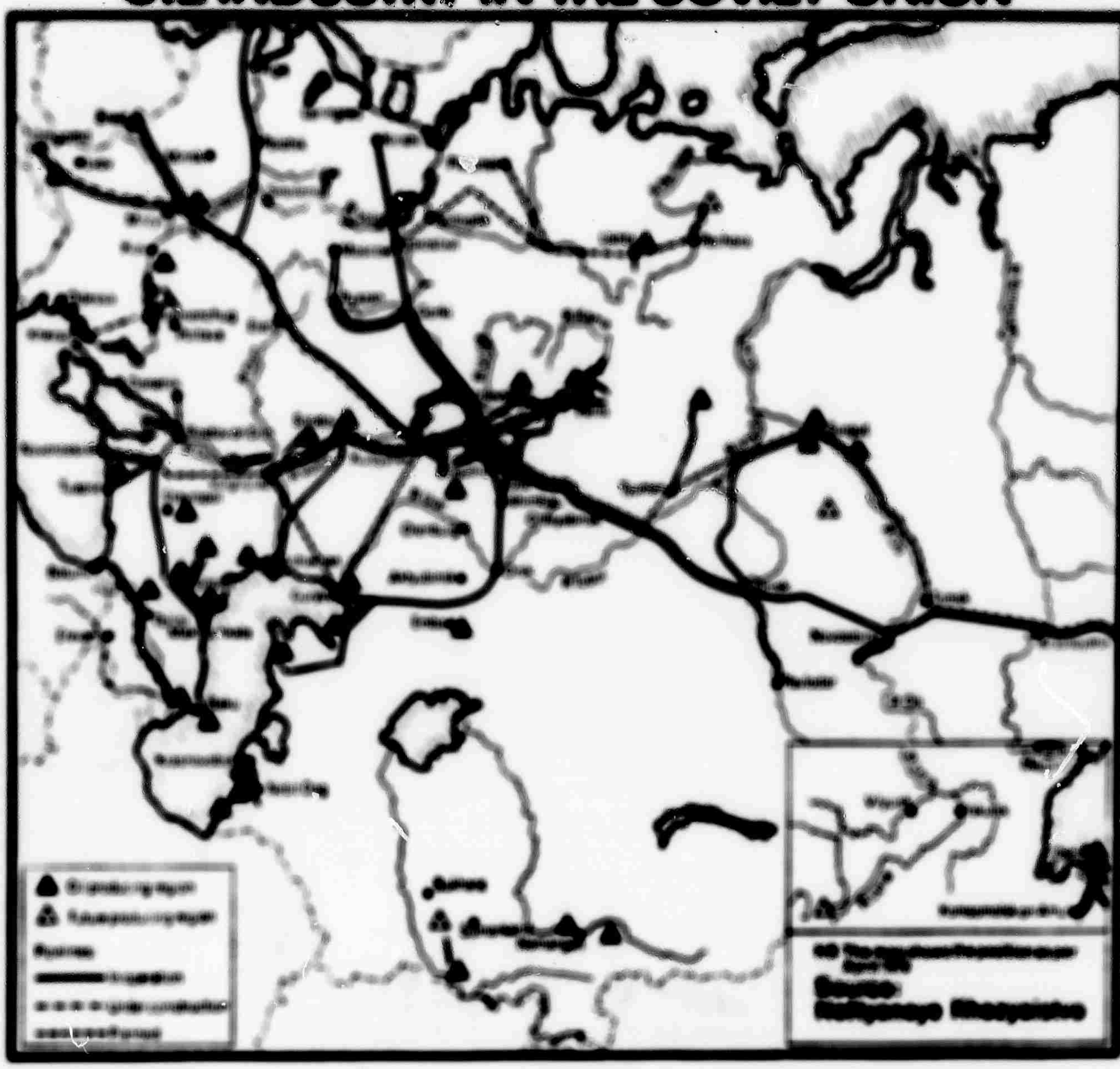


Figure 25

Petroleum Press Service September 1970

Oil has been known in one locality in the Soviet arctic since the second half of the seventeenth century, in the Ukhta region of Komi ASSR, known as the Timano-Pechorskaya petroliferous province.[73] However, most of the crude petroleum production in the U.S.S.R. has been from regions south of the Arctic Circle. The situation has been changing in recent years and forecasts for the future are of staggering dimensions. For example, it is forecast that by 1975 the West Siberian basin will be the U.S.S.R.'s largest producer, and that by 1980 it will be producing 40 percent of the total U.S.S.R. oil production.[74] Despite unusually high capital investment expenses in arctic areas, the cost of Western Siberian crude is already down to the average for the U.S.S.R. as a whole, and by 1972 it is expected to be the least expensive in the country.

Figure 26 shows the principal sedimentary basins favorable for petroleum. Oil and gas exploration has been and is being pushed in several arctic areas of the U.S.S.R. and the amounts of known or estimated potential reserves on land and offshore have been increasing at a tremendous rate.[75] The Soviet Minister for the petroleum industry, in an interview last year, stated that, "The U.S.S.R. has Siberian oil coming out of its ears - - or at least will have."[76] He forecast that 75-80 percent of the increase in Soviet oil production in the next five years will come from Siberia. Recent estimates are that of the 400,000 b/d jump in Russian crude production in 1971, about 260,000 b/d or 65 percent will come from western Siberia.[77] Western Siberian production is planned to reach 2 million barrels a day by 1975 and double that by 1980.[78] By 1980 it should be producing more than 40 percent of the total national output.

FIGURE 26 ARCTIC GAS AND OIL

A 1970 Soviet decree in fact envisaged a higher production by 1980, up to 230 - 260 million metric tons, which was estimated as 40 percent of the probable total output at that time.(78)

Like the Canadian arctic oil reserves, the U.S.S.R. reserves, known to be great and assumed to be enormous, have not yet been established as proved or fully known. Total reserve estimates are therefore reflections of estimates based on the factors of geological structures, application of formulas and similar well known methods of calculating possible potential.

Siberia's major on-shore oil province is the Ob - Yenisei River Basin between the Urals and the central Siberia platform. There are said to be 60 fields north of Tyumen, and Soviet geologists estimate that 75 billion barrels of oil have been proved.(79) Peak output for that basin has been projected as high as 15 million barrels per day.

Another source has stated that at least 40 billion barrels of "proved plus probable" oil have been discovered in the Soviet arctic. The ultimate reserve, they state, will be more than three or four times these amounts. They conclude that the Russian arctic unquestionably is one of the richest hydrocarbon provinces on earth.(80) Soviet authorities are cited as having stated that at least 40 percent of the U.S.S.R.'s potential oil reserves are in the Arctic or near-arctic regions.(81) Although not fully known, the off-shore areas along the 4500 miles of the U.S.S.R. arctic coast, from Norway to the Bering Strait, are thought to embrace gigantic areas of geologically favorable formations. Included are the Barents Sea, Kara Sea, and the Laptev Sea. The Pechora West Siberian and the Khatanga petroliferous basin reportedly extend far out on the coastal shelves.(82) A University of Utah geologist, A.J. Eardley, last year estimated that the off-shore

continental shelf of U.S.S.R. Siberia contains a reserve of 200 billion barrels of oil.[75] If the above estimates are valid, it would mean that the Soviet arctic, including onshore and offshore areas, may contain oil reserves nearing the half-trillion range. By comparison, the world published "proved" reserves in 1969 totalled 545.6 billion barrels.[62]

Gas reserves in the Soviet arctic are believed to be even more impressive (see Figure 27). For example, it is reported that not less than 500 trillion cu ft. have already been proved.[49] It is conjectured that the total may well run three or four times that amount. The off-shore areas alone are estimated to have 500 trillion cu ft.[75] Again, based on published estimates of potential reserves, the total for the Soviet arctic might reach the 2 to 3 quadrillion range.

By comparison, Soviet gas consumption last year (1970) was 7.06 trillion cu ft. The government's target for 1975 is about 11.00 trillion cu ft from the Tyumen Province in Western Siberia.[61] It would then be the U.S.S.R.'s No. 1 gas producer.

The 2 to 3 quadrillion estimate may also be compared with the data released by Soviet planning officials last year relating principally to the West Siberian gas fields.[61] They reported that as of January 1, 1970 they had 24 "untapped" or "virtually untapped" gas fields, each with at least 3.5 trillion cu ft of proved-plus-probable reserves. They placed the total proved reserves at more than 290 trillion cu ft for the 24 fields and the "probable" total at 637.3 to 672.6 trillion cu ft. Russia's total proved reserves at the beginning of 1970 were 425.9 trillion cu ft, which was 15 trillion more than U.S. proved reserves as of that date. Russian officials

GAS INDUSTRY OF THE SOVIET UNION

Figure 27

[illegible]

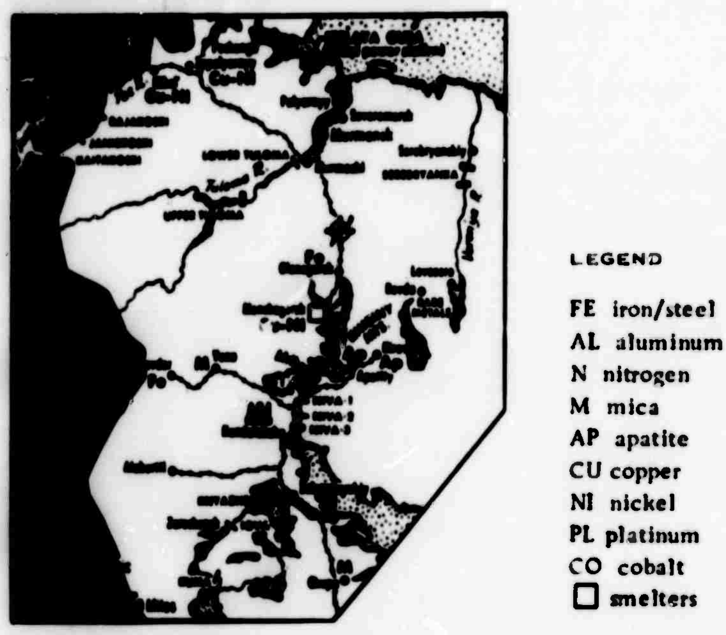
told the International Gas Industry Congress in Moscow last year said that they expect proved gas reserves to reach 760 to 882.5 trillion cu ft by 1980.[64] At 1970's planned production rate - 6.9 trillion cu ft ---Russian has almost a 62 year proved gas supply, as compared with a 13.4 year's supply for the U.S. Western Siberia alone has 57 percent of the U.S.S.R.'s total. Alex Sorokin, President of the International Gas Union, and Deputy Minister of the U.S.S.R.'s gas industry, reported at the Moscow Congress that potential Soviet reserves now total 2.9 quadrillion cu ft, up from 2.5 quadrillion a year earlier.[64] He stated that gas now accounts for nearly 20 percent of the U.S.S.R.'s fuel output, and that he expected that percentage to rise to 35.2 by 1975. It would appear from Soviet sources that the potential 2 quadrillion cu ft of gas resources in the Soviet arctic is a reasonably low estimate.

3.4.2 <u>Other Minerals</u>

Figure 29 shows the metal industries for the Kola Peninsula and Central Siberia.

The Kola Peninsula has an integrated system from the mining to the output of finished metals for nickel and copper. Monchegorsk is the center of the nickel-copper industry, with a smelter and a refinery. Its nearby mine is largely depleted. The Pechenga complex is also approaching depletion, but a new deposit is being developed east of Nickel. Iron ore is mined at Olenegorsk and Kovdor, with a combined output of 6 million tons of concentrate in the mid-60's. Olenegorsk proven reserves are placed at 300 million tons and indicated reserves at twice that amount.[71] Kovdor has the U.S.S.R.'s largest deposit of vermiculite, used in fire-resistant

KOLA PENINSULA METALS



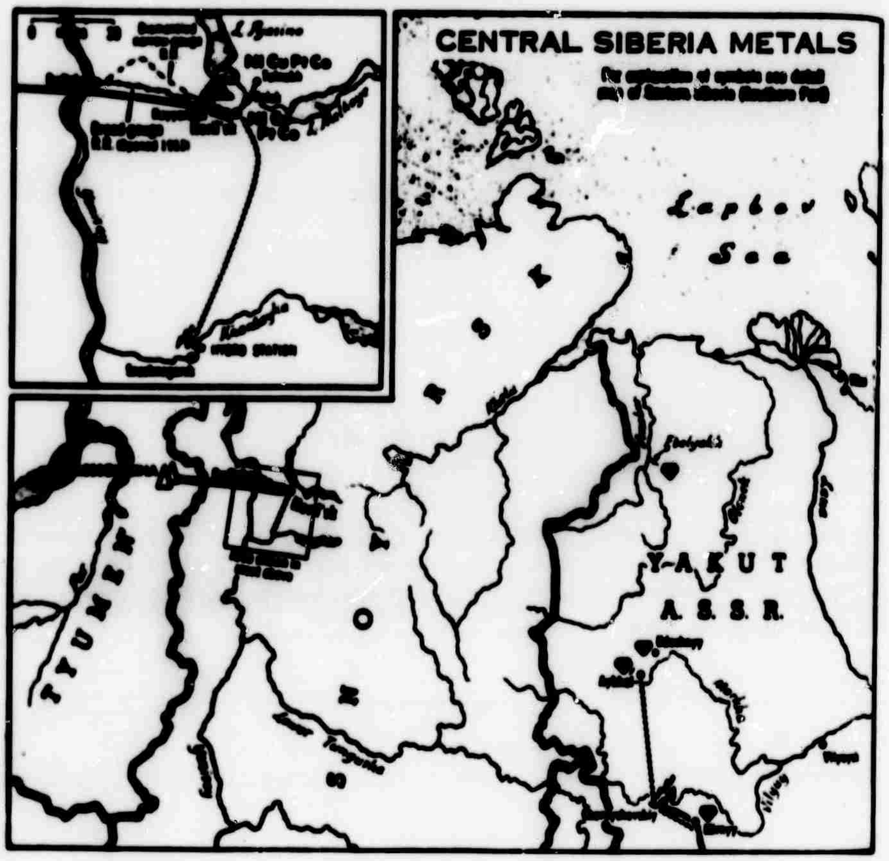


FIGURE 28 KOLA PENINSULA AND CENTRAL SIBERIAN METALS

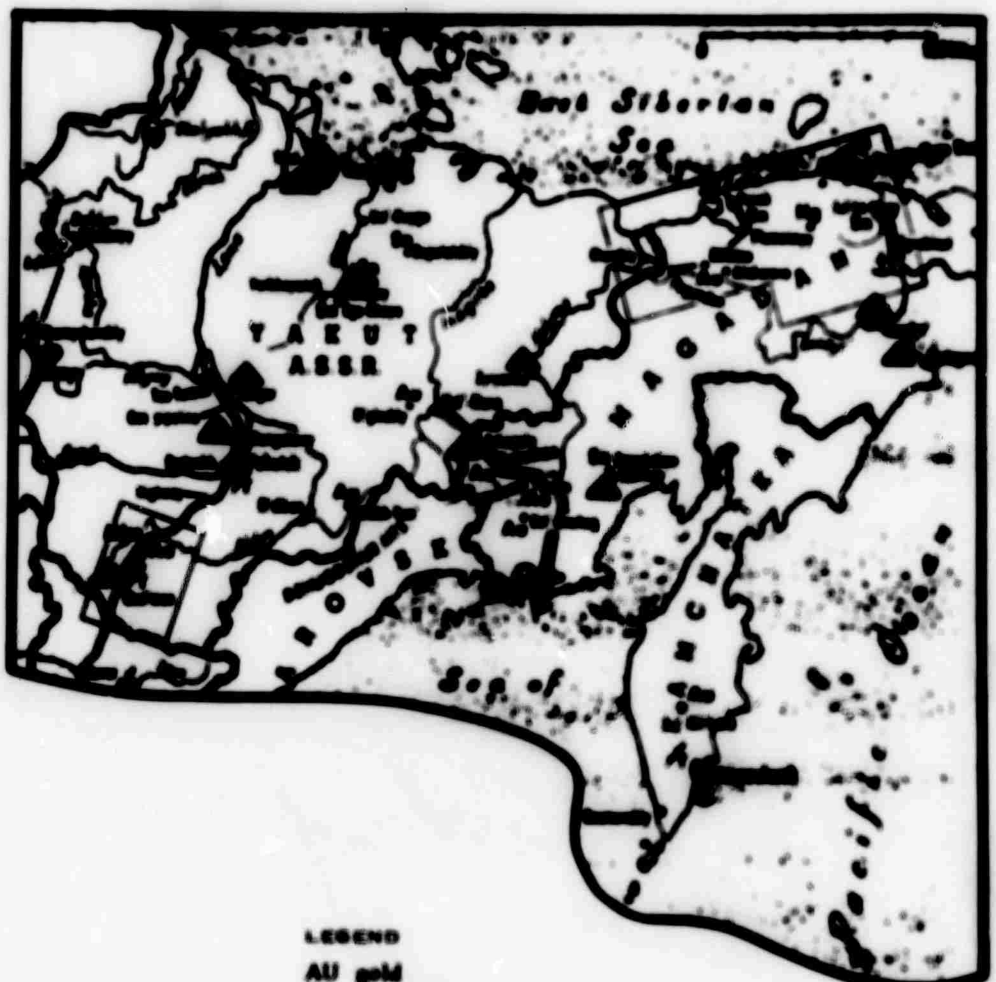
building materials. Mica also is mined there. A commercial deposit of columbium and tantalum is operated east of Kirovsk. The Pechora area also has deposits of fluorspar and some lead ores.

Norilsk, in Central Siberia, is a center for the mining of nickel and copper, polladium, platinum, selenium, tellurium, titanium, and canadium. The Yarega titanium deposit has the potential as the most economic source of raw material for a number of titanium - magnesium combines in the U. S. S. R. (71)

Figure 29 shows the Soviet east arctic resources. (65) Tin mining is concentrated in the basin of the Yana River. A diamond center is being developed at Aykhal. Tin is also mined on the northeast coast near Pevek and Iul'tin, which also produces tungsten. Gold mining occurs around Bilibino and at Komsomolsky and Polyarnyy. A mercury deposit is worked at Plomennyy.

The relative importance of the Soviet Union's metal industries in the Arctic is shown in Figures 30 through 34. (65) Most of the iron and steel industry is outside arctic U. S. S. R. The Kola Peninsula did supply 5.5 million metric tons of iron ore in 1965, compared to a total U. S. S. R. production of 153 million tons.

Of the ferroalloys, the Soviet Arctic does not supply any significant amounts of manganese, chromium, molybdenum, vanadium, and zirconium. The Kola Peninsula and Norilsk supply two-thirds of the U. S. S. R.'s 80,000 - 90,000 tons of nickel. The arctic nickel deposits are now the Soviet Union's principal source of platinum-group metals. Virtually all of the cobalt is associated with nickel production, both in the Arctic and in the southern Urals, with a ratio of 1 ton of cobalt for every 70 tons of nickel. The large tungsten deposit at Iul'tin is supplemented by other



LEGEND

AU gold
SN tin mines
SN tin mills
diamonds
M mica
W tungsten
HG mercury

FIGURE 29 EAST ARCTIC RESOURCES

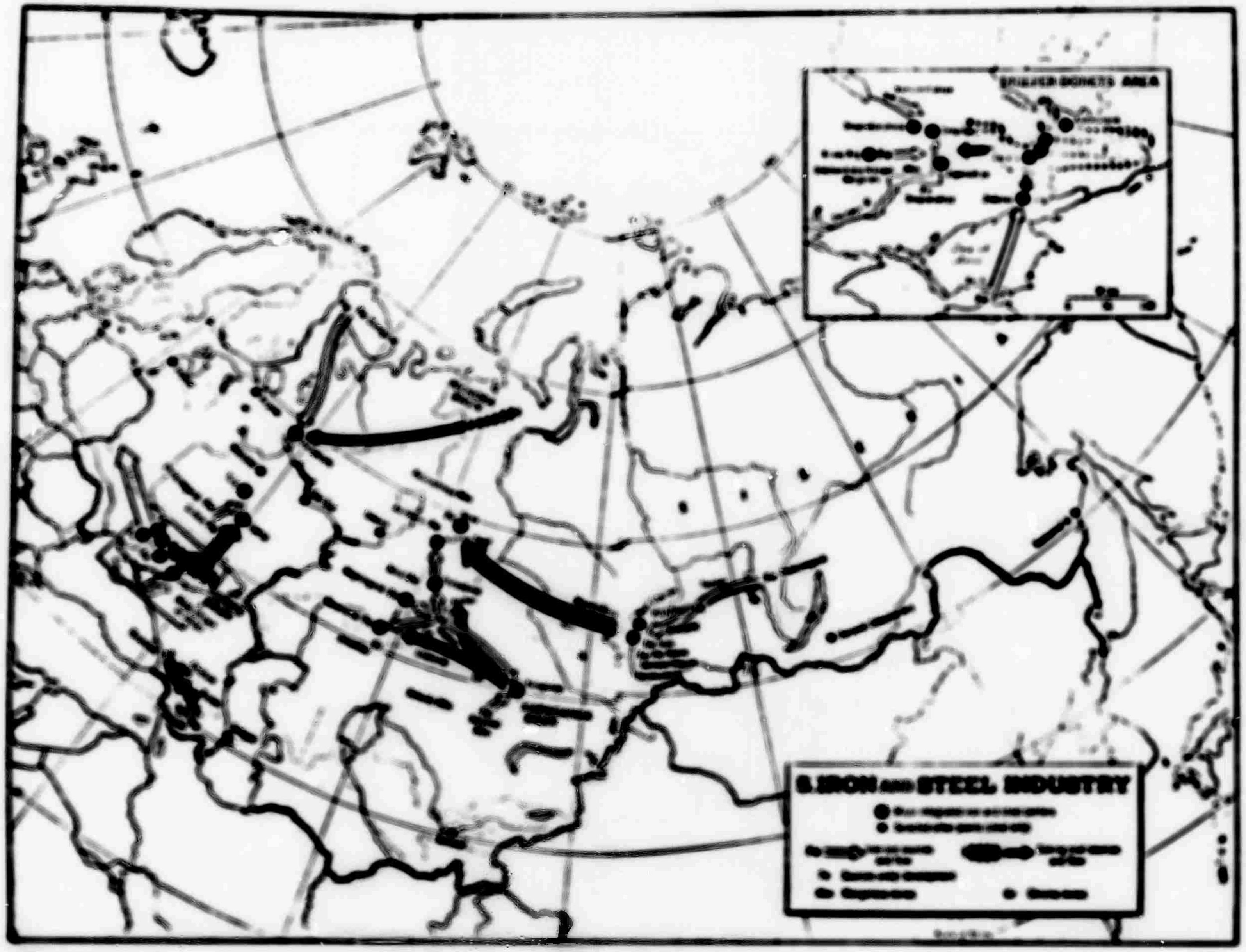


FIGURE 30 IRON AND STEEL INDUSTRY

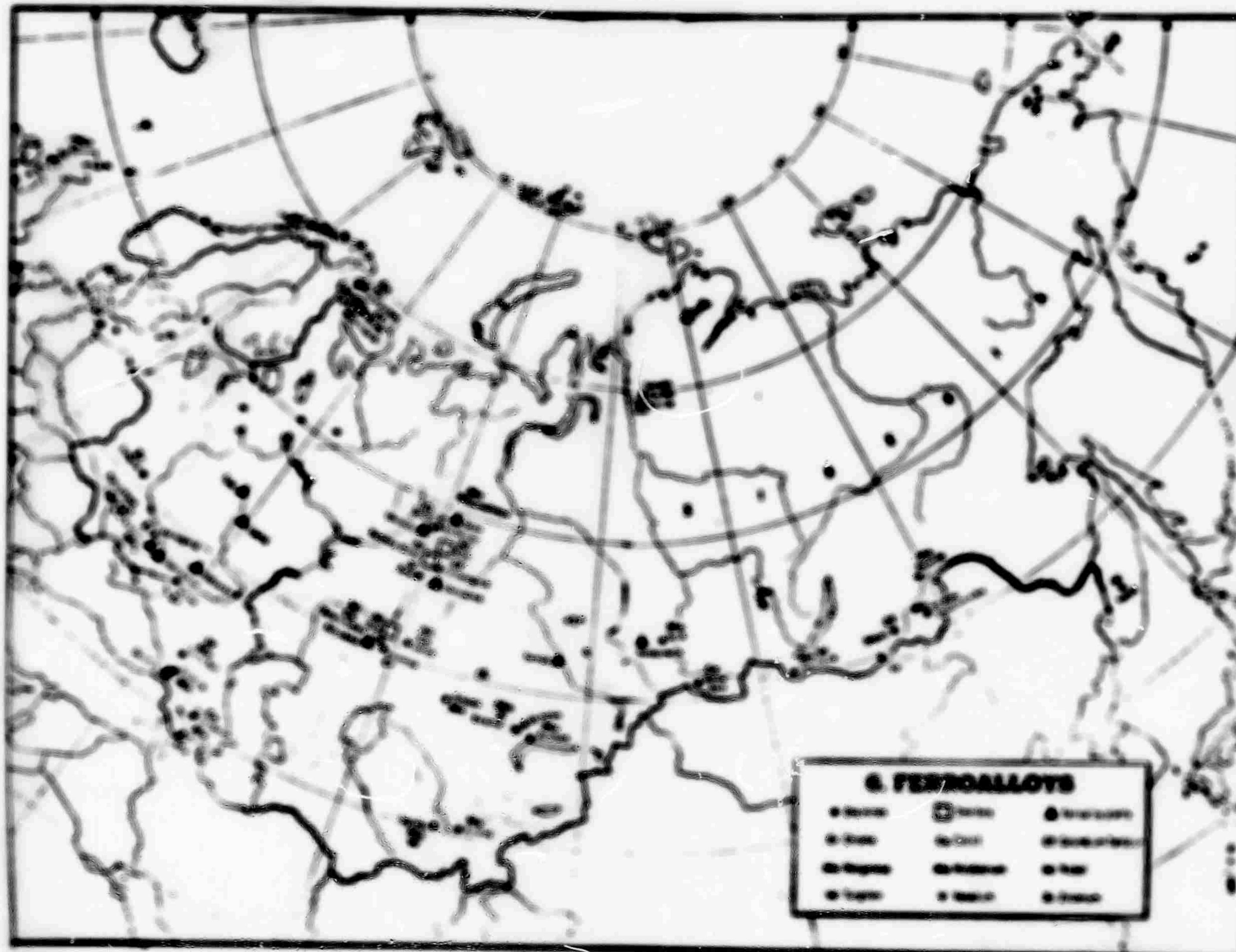


FIGURE 31 FERROALLOYS

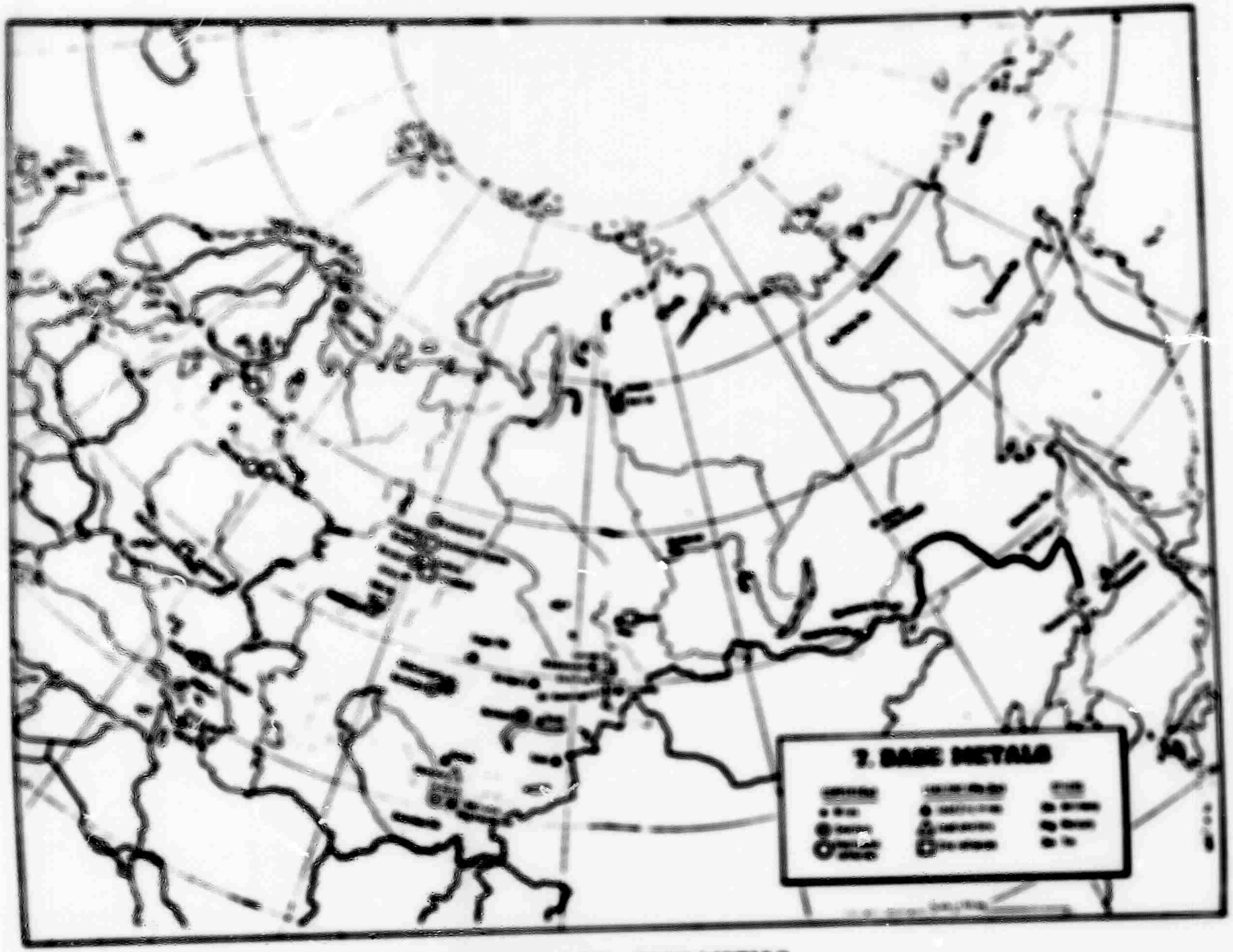


FIGURE 32 BASE METALS

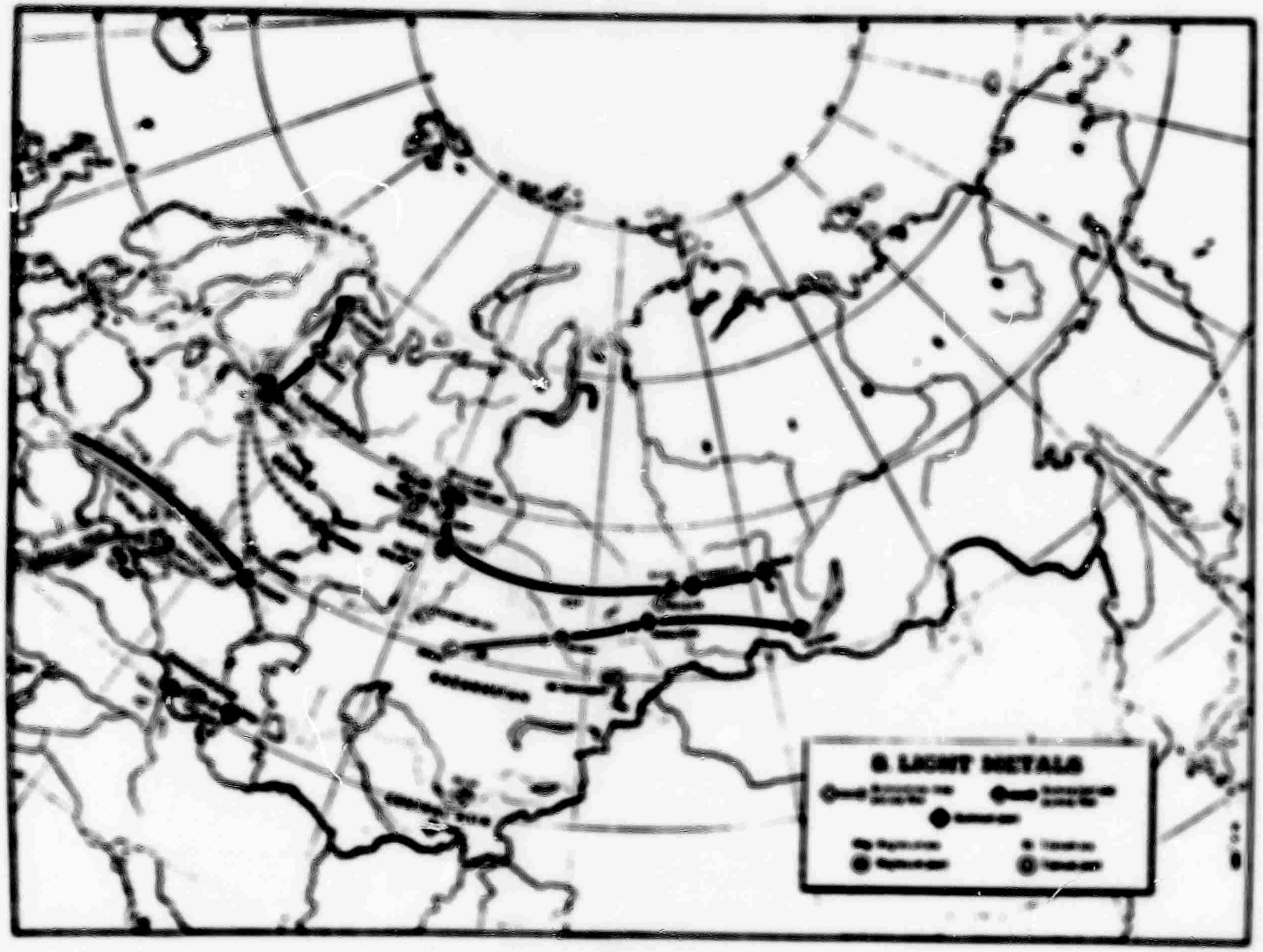


FIGURE 33 LIGHT METALS

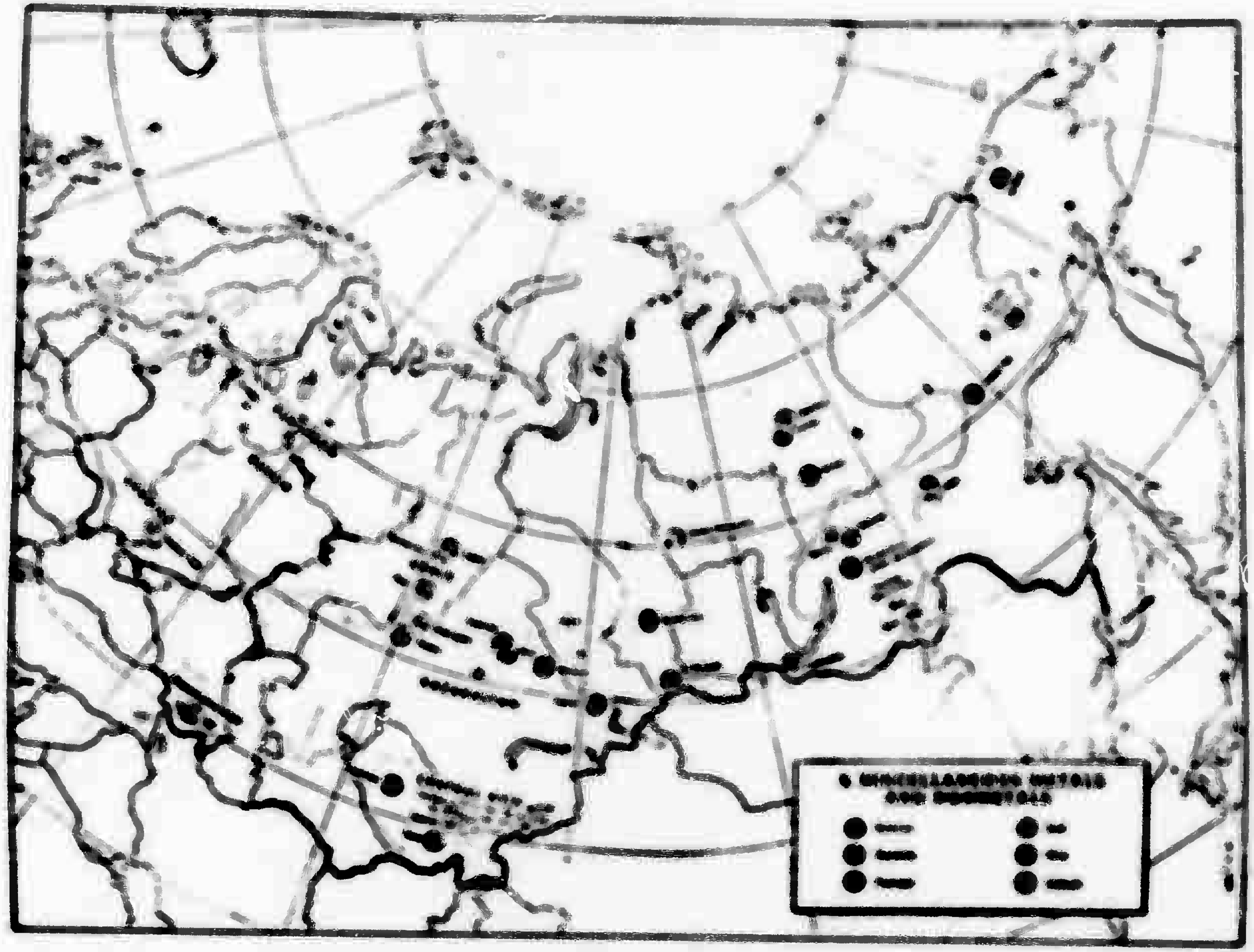


FIGURE 34 MISCELLANEOUS METALS AND NONMETALS

deposits in the Caucasus and Central Asia. The principal source of columbium and tantalum is the Kola Peninsula.

Of the base the Soviet arctic does not supply any lead or zinc. Copper is a coproduct of nickel in the arctic mining centers of Norilsk and the Kola Peninsula. However, copper is produced at many other areas with central Asia producing more than half the copper smelter output. The far east arctic is a key source of tin at Ege-Khaya, Deputatskiy, and Iul'tin, supplemented by east Asian sources. Mercury production is concentrated in central Asia with a new deposit being developed in the far east arctic at Plamennyy.

Of the light metals the Soviet arctic is a significant producer only of aluminum. Nepheline concentrate, obtained as a byproduct of apatite production in the Kola Peninsula, is reduced at Volkhov and Pikalevo and then supplied to the aluminum mills at Kandalaksha. However, southern Siberia is expected to produce 65 percent of the planned 1970 output of aluminum, or 2 million tons.

Gold mining is concentrated in the Urals and in Siberia, including newly discovered placer deposits in the Kolyma district and around Bilibino in the Arctic. However, lode deposits are being developed elsewhere in central Asia. No uranium, asbestos, or graphite is processed in the Arctic. Diamond production is concentrated at Mirnyy, Aykhal, and Udachnyy in the east arctic. Only minor amounts of fluorspar are worked at Amderma in the Pechora Basin in the Arctic, while most production occurs in Central and east Asia. Muscovite sheet mica is obtained from the Kola Peninsula area and from the Mama River district of Irkutsk Oblast in eastern Siberia.

A.4.3 Industry, Forestry, and Agriculture

A.4.3.1 General

The Soviet Arctic is not of a significant importance in many areas of the Soviet economy. This includes industrial areas which are still concentrated in European Russia around the larger cities. Most of the electricity is produced south of the Arctic Circle. The iron and steel industry is concentrated in the Ukraine and Urals. The Soviet Arctic has not yielded to date significant quantities of important industrial metals such as manganese, chromium, molybdenum, vanadium, zirconium, lead, zinc, and magnesium; nor has it produced uranium, asbestos, or graphite. The machinery, synthetic rubber, nitrogen, chemical fibers, and consumer-goods industries are all well below the Arctic Circle near population centers. Farming in the Arctic is negligible except for limited areas in the southern parts of some river basins. Some cattle are raised in these same southern Arctic areas. Reindeer herds are used for food and other products.

In the chemical industries, the Soviet Arctic plays an important role in fertilizers, but not at all for nitrogen, salts, alkalies, synthetic rubber, or chemical fibers. The rich apatite deposit of the Kola Peninsula is the principal raw material used at most Soviet superphosphate plants and accounts for 80 percent of the raw material used in superphosphate manufacture. (Figure 35).

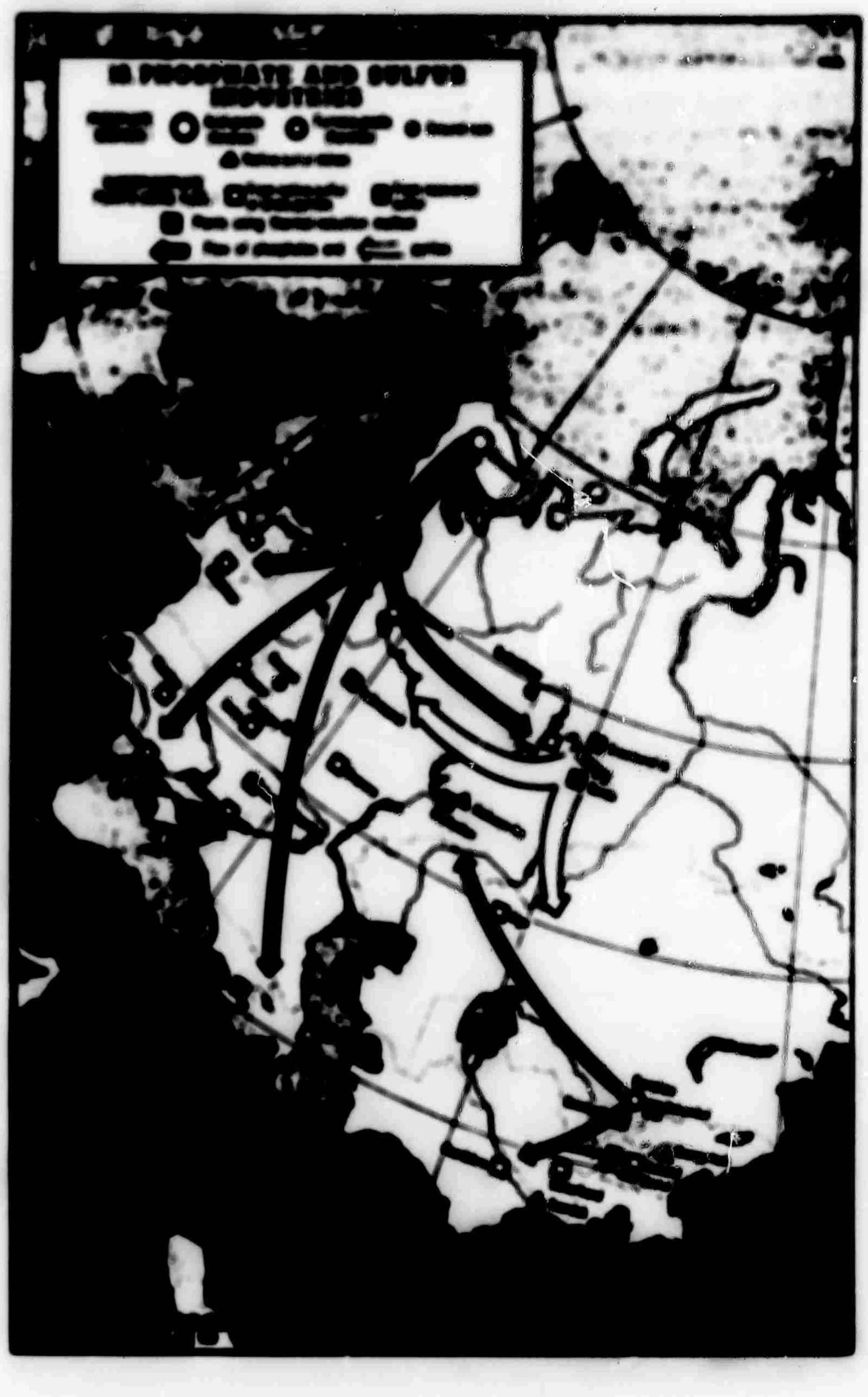


FIGURE 35 PHOSPHATE AND SULFUR INDUSTRIES

A.4.3.2 Centers of Production

A.4.3.2.1 The European North

The Murmansk Oblast has as much as 40 percent of the U.S.S.R.'s phosphorus resources (the chief apatite reserves), about 20 percent of the ceramic raw materials (feldspar, pegmatite), more than 95 percent of the kyanite, large reserves of micaceous raw material, including vermiculite, and very large reserves of abrasive materials (garnet). [71]

The largest industrial center in the world bordering the Arctic Ocean is Murmansk. It is an ice-free, well-protected water area of great economic and strategic importance. As the northernmost open winter port of the U.S.S.R., it is the capital and educational center for the Kola Peninsula area. Murmansk is a center for shipbuilding, ocean trawling fleet, fish processing, transocean shipping, and the terminal of the Northern Sea Route. [85] Fishing accounts for about half of the Murmansk Oblast gross industrial product. The Murmanskcoasts are ice-free most winters, due to the Norwegian Coastal Current extension of the Gulf Stream

Archangel on the White Sea is the largest far-northern city in the world. It is a center for lumber industry and exports lumber, resin, turpentine, and furs. It has the largest saw mills of the U.S.S.R. Even though the harbor is frozen from November through May, requiring the use of icebreakers, it is an important port.

The Kola Peninsula and White Sea area also have a number of medium-size cities. Severodvinsk, Severmorsk, and Polyarnyy are Navy bases.

Most of the other cities there are associated with the mining and lumber industries.

In the Pechora Basin, the most important center is Vorkuta. It is a center for coal mining and geological research. Naryan-Mar is a port for both river- and sea-going ships at the mouth of Pechora and is an important timber port. Amderma on the Arctic coast of the Kara Sea is a port on the Northern Sea Route and a research center for geologists and construction engineers.

Agricultural specialization by the individual oblasts and autonomous republics has been suggested as: dairy, beef, and poultry farming and (near cities) truck gardening in the southern part of the Karelian A. S. S. R.; dairy, pork, potato, and vegetable production in the southern part of Arkhangel'sk Oblast and Komi A. S. S. R.; and reindeer breeding, fur trapping, individual centers of farming, and livestock raising in the Murmansk Oblast and the northern parts of the Arkhangel'sk Oblast, Karelian, and Komi A. S. S. R.'s. (71)

Total forest reserves of the Komi A. S. S. R. are 2.7 billion cubic meters. By 1970, the total volume of logging operations there could be brought up to 23 million cubic meters. (71) At the present time, Archangel Oblast, which holds first place in the U. S. S. R. shipments of timber, ships out 13-14 million metric tons of timber by rail. (71)

A.4.3.2.2 West Siberian North

The west Siberian lowlands have timber reserves over an area exceeding

2 million square kilometers and are estimated at 8 billion cubic meters.[71] Future timber production could reach 28 million cubic meters annually.

Western Siberian agriculture is limited by the short growing season (at the latitude of Salekhard it is about 100 days), insufficient heat, prolonged north winds, and the threat of summer frost. Fast-ripening varieties of cereal crops (winter rye, oats, barley, and wheat), most fodder crops, potatoes, and vegetables can be grown in the Khanty-Mansi National Okrug. The total mean annual fish catch in the Ob-Irtysh Basin from 1955 to 1964 was one-third the catch for the U.S.S.R. and about 70% of the total catch for Siberia.

In the west Siberian basin, the largest city is the metal mining center of Norilsk. Salekhard is a river port at the mouth of the Ob and a center for the wood industry. Dudinka is at the mouth of the Yenisey River and serves as the port for Norilsk. Dikson is an island off the mouth of the Yenisey and has been used as an anchorage and refueling point for ships on the Northern Sea Route. Igarka on the Yenisey is the largest timber center in Siberia.

A.4.3.2.3 Central and Eastern Siberian North

The central and eastern Siberian industrial centers consist mainly of small ports on the major rivers emptying into the Arctic Ocean and the industrial city of Yukutsk on the Lena River. Yukutsk is a center for coal mining and a natural gas field. Nordvik and Ambarchik are small anchorages and transshipment points. Tiksi at the mouth of the Lena River

is the transshipment point for all goods coming in by sea to the Yakutskaya A.S.S.R. Pevek (700 miles east) is the port of the tin-mining region of western Chukotka.

A.4.3.3 Prospects for the Future

Concentrated in the Soviet European North in 1965 were: 100 percent of the national output of apatite concentrate, 17.5 percent of timber shipments, 12 percent of lumber production, 27.7 percent of the wood pulp, 18 percent of the paper, and 15.6 percent of the fish catch. (71) In the foreseeable future, the Soviet European North will extend its specialization in the timber, pulp and paper, woodworking, chemical, fuel, fishing, nonferrous metallurgy, and machine-building sectors and expand its specialization in the titanium industry. (71) Specifically, the Archangel Oblast is expected to extend its specialization in the timber, pulp and paper, woodworking, and fishing industries and in machine-building; a nonferrous metallurgy sector will emerge; and metal-working, manufacturing of building materials, and individual sectors of the food and clothing industries will be initiated.

The Murmansk Oblast is intensifying its specialization in nonferrous metallurgy and the chemical, mica, iron ore, and fishing industries, as well as developing metalworking, the production of building materials, and individual sectors of the food and clothing industries.

The Karelian A.S.S.R. undoubtedly will extend its specialization in the pulp, paper, woodworking, mica, and fishing industries; machine-

building, nonferrous metallurgy, and manufacturing of building materials. Individual sectors of the food and clothing industries, and electric and thermal power production may also be expected to undergo further development.

The Komi A.S.S.R. almost certainly will intensify its specialization in the timber, pulp, paper, woodworking, coal, carbon black, gas and oil production, and oil refining industries, and expand its industrial specialization in the titanium and chemical industries. Production of electric power and building materials, as well as individual sectors of the clothing and food industries, will also be developed.

In western Siberia the main production will continue to be raw materials. Important reserves are oil natural gas, timber, peat, coal, and iron ore. Rich reserves suggest that the region will specialize primarily in the production and partial processing of oil and gas, the shipment and chemical-mechanical processing of wood, and the petrochemical industry.

Central and eastern Siberia undoubtedly will continue the mining and production of nonferrous metals and minerals, such as gold, diamond, tin, mica, and coal.

A.4.4 Population

The population of the Soviet Arctic is greater by far than any other parts of the Arctic and is estimated to be about 4.5 million (see explanation below). This includes the river basins adjacent to the arctic coastline. Most of the population is concentrated in the Kola Peninsula and White Sea area, as

shown in Figure 34.[66,67] Other population concentrations are along the Pechora, Ob, Yenisey, Lena, and Kolyma Rivers that empty into the Arctic Ocean.

Table 9 shows the major U.S.S.R. cities in the Arctic.[66,88] Archangel and Murmansk both have populations of about 300,000. Six other cities have populations of 10,000 and more. According to Izvestiya, October 2, 1966, Murmansk is expected to double its population by 1980.

The U.S.S.R. population in the arctic area was estimated, using the administrative divisions and populations in the mid-1960's as follows:[66,71]

Administrative Area	Population
Murmansk Oblast Archangel Oblast Karelian A.S.S.R. Komi A.S.S.R.	3,700,000 [71]
Nenets National Okrug	37,000
Yamal-Nenets National Okrug	64,000
Khanty-Mansi National Okrug	134,000
Taymr National Okrug	33,000
Evenki National Okrug	10,000
Yakut A.S.S.R.	527,000
Chukchi National Okrug	52,000
	4,557,000

It is estimated that in the mid-1960's the U.S.S.R. population in the arctic area was about 4.5 million. This amounted to about 2 percent of the total U.S.S.R. population.

It is estimated that there are nearly half a million military personnel in the Soviet Arctic Command, with many around the White Sea area and some in North Siberia.[89] Russian census figures list military personnel at their place of recruitment, which in most cases is not the Soviet Arctic. In addition, there are probably an undetermined number of

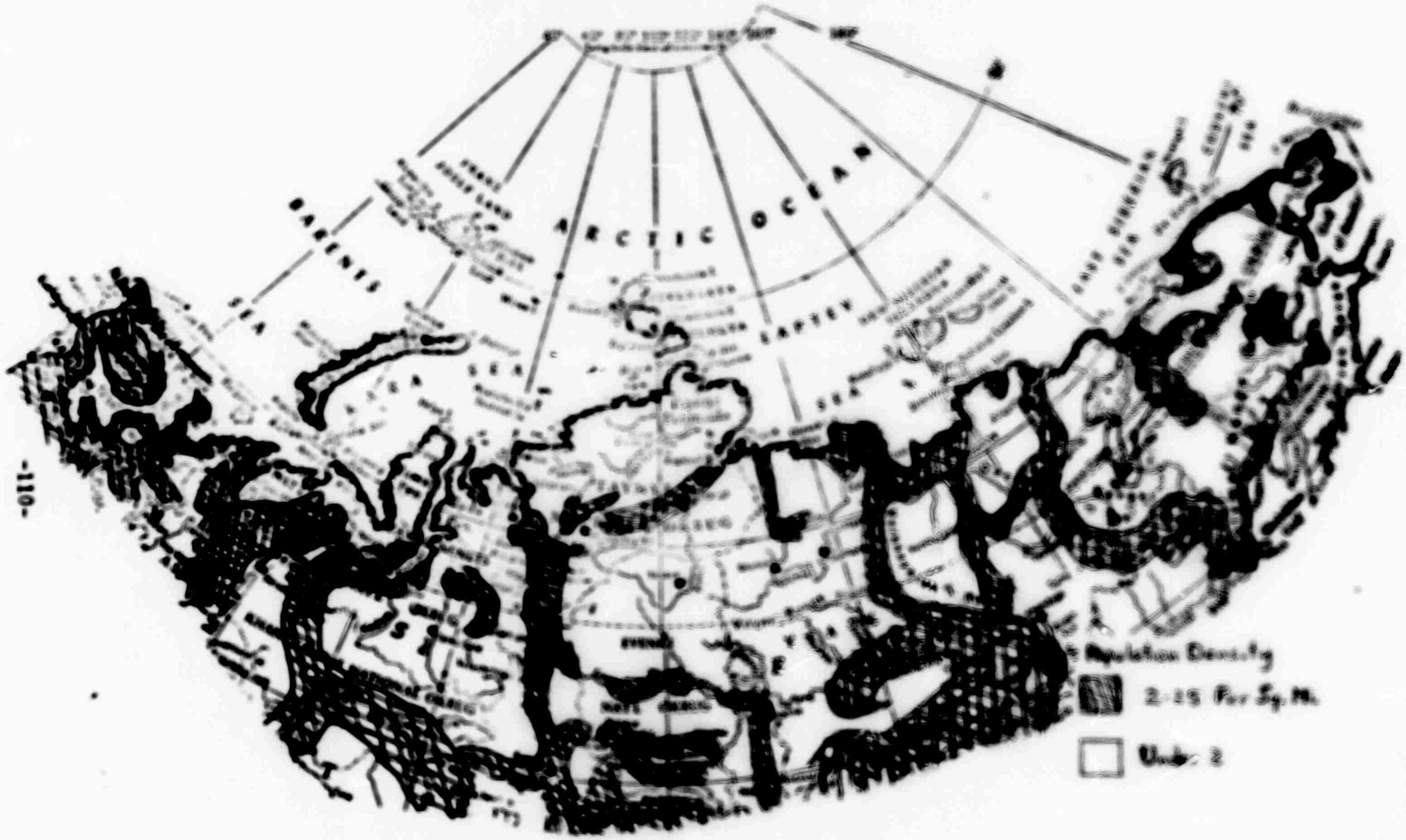


FIGURE 36 SOVIET ARCTIC POPULATION

TABLE 9 MAJOR U.S.S.R. CITIES IN ARCTIC

Archangel	303,000	Naryan-Mar	11,400
Murmansk	272,000	Amderma	10,000
Norilsk	124,000	Dikson	10,000
Yakutsk	89,000	Kem	10,000
Severodvinsk	78,657	Khatanga	10,000
Vorkuta	63,000	Kuolayarvi	10,000
Kirovsk	55,000	Yessey	10,000
Monchegorsk	54,000	Mezen	7,300
Kandalaksha	37,065	Pevek	5,800
Inta	36,154	Berezovo	5,700
Ukhta	36,154	Olekminsk	5,500
Severomorsk	32,234	Turukhansk	5,000
Pechora	30,586	Anadyr	4,600
Polyarnyy	30,000	Vilyuysk	3,600
Yartsevo	25,558	Nordvik	2,500
Vereshchagino	22,800	Ust' Maya	2,300
Khanty-Mansiysk	20,677	Tura	2,100
Apatity	19,938	Golchikha	1,300
Segezha	19,708	Verkhoyansk	1,200
Belomorsk	17,400	Tiksi	1,000
Dudinka	17,000	Allaykha	800
Onega	17,000	Ambarchik	800
Salekhard	16,557	Bulun	800
Nikel	16,305	Indiga	800
Igarka	14,300	Kazachye	800
Pechenga	13,200	Uelen	800

economic and political pressures in Siberia.

A.4.5 Transportation

The transportation in the U.S.S.R. Arctic is made up of sea, river, motor roads, and air modes as shown in Figures 37 and 38.[60, 90] Rivers are the primary transportation routes for the arctic interior lands. These are tied together in the Arctic Ocean by the Northern Sea Route. To the south they are tied together by the Trans-Siberian and other railroads. Except for a motor road paralleling the railroad in the Kola Peninsula and Yakutsk in the far eastern part of Siberia, year-round roads are practically nonexistent in the Soviet Arctic. Pipelines were treated in the previous section on fuels.

A.4.5.1 Rivers

Most of the U.S.S.R. arctic rivers are navigable some distance inland part of the year. The Ob, Yenisey, and Lena rivers are navigable all the way to the Trans-Siberian Railway. However, they are frozen over a good portion of the year as follows:[91]

Ob - 220 days

Yenisey - 168 days

Lena (upper reaches) - 220 days

(lower reaches) - 275 days

A canal connects the White and Baltic seas permitting river traffic between Leningrad and Archangel. River and canal waterways are used extensively

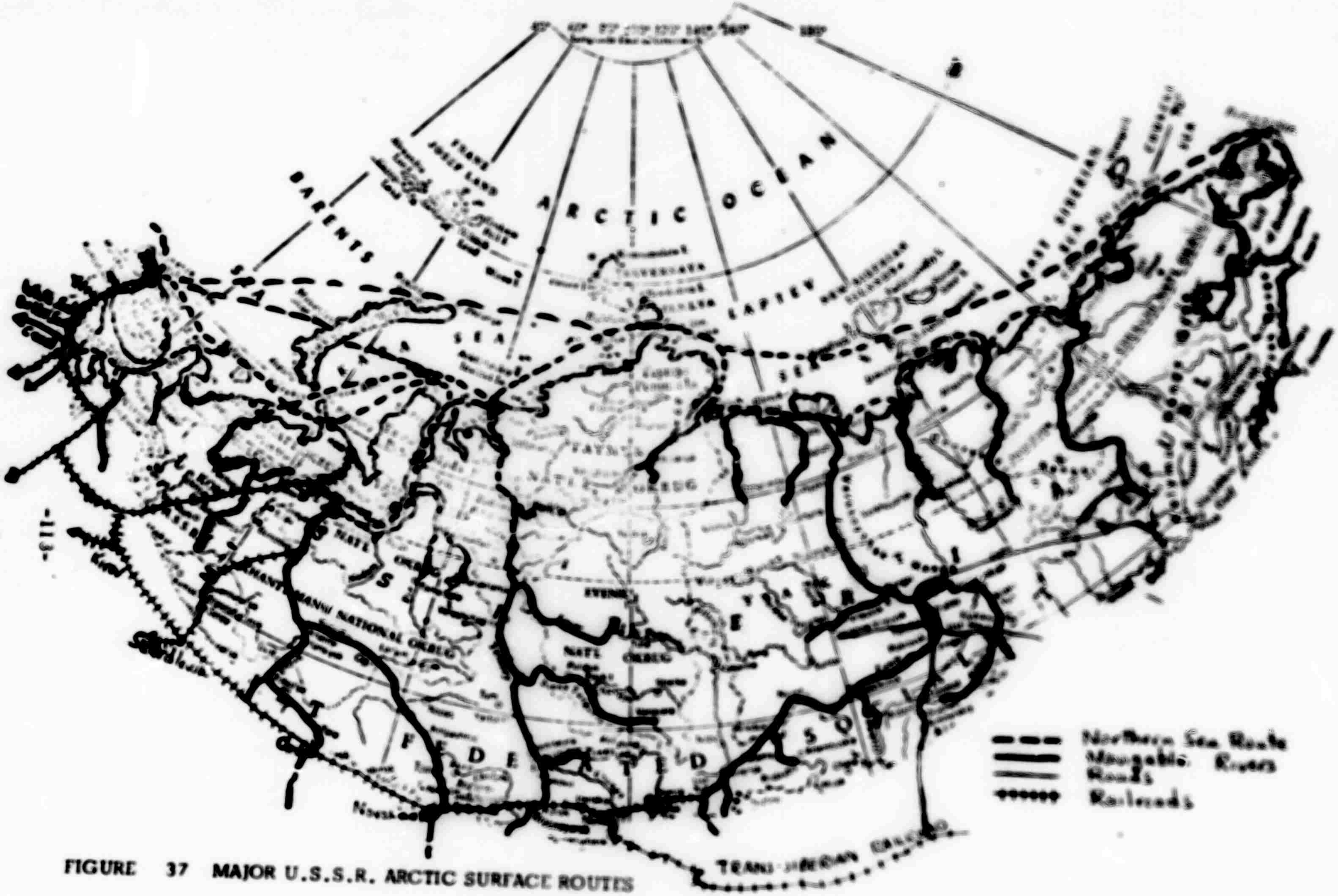


FIGURE 37 MAJOR U.S.S.R. ARCTIC SURFACE ROUTES

TIGURE 38 MAJOR U.S.S.R. ARCTIC AIR ROUTES

in the U.S.S.R. and their importance is constantly increasing - second only to railroads.

The rivers of the Pechora Basin provide excellent waterways for floating timber to pulp mills. Thus, Naryan-Mar on the southeast side of the Pechora River delta is a timber port of growing importance. The Siberian rivers are navigable their entire length for about four months only. During the winter months, when thick ice covers the rivers, over-snow vehicles and sledges are used.

The river freighting will be expanded in the future. On the Ob-Irtysh, the freight in 1980 is expected to be 35 million metric tons, three times the present figure.[57] This will be due to the oil and gas developments in the area.

A.4.5.2 Railroads

There is a well-developed network of railroads on the Kola Peninsula linking industrial and mining centers. The principal line runs from Murmansk to Belomorsk and then to Leningrad via Petrozavodsk or to Moscow via Vologda. The line extends north and west from Murmansk to Nikel. Branches extend from Olenegorsk to Monchegorsk, from Apitity to Kirovsk, and from Pinozero to Kovdor. Branches also extend to the Finnish border.

In the Pechora Basin, Vorkuta is linked to the main U.S.S.R. railroad network with a double-track electrified line. Northward the railroad extends to the port of Kara on the Arctic coast of the Kara Sea.[90]

Eastward the railroad crosses the northern Urals to Labytnangi, on the lower Ob opposite Salekhard.

In the Siberian Arctic, the only other railroad besides the previously mentioned one to Labytnangi is a short line between Dudinka on the Yenisey River and Norilsk. A line was started in the early 1950's from the mouth of the Ob eastward to Igarka but later abandoned. Opening of oil and gas fields in this region may force its completion and possible extension to Dudinka. (59)

A.4.5.3 Northern Sea Route

The Northern Sea Route consists of a system of shipping lanes along the Arctic coasts of the U.S.S.R. from the straits between the Barents and Kara seas to the Bering Strait. It is considered to include extensions to Murmansk and Archangel at its western end and to Vladivostok at its eastern end, as well as to branches at various ports along the navigable rivers flowing into the Arctic Ocean. The principal seaports and river ports along the route are Naryan-Mar on the Pechora River; Amderma at the southwestern end of the Kara Sea; Novyy Port on the Gulf of Ob; Salekhard at the mouth of the Ob River; Dickson, Dudinka, and Igarka on the Yenisey River; Nordvik at the southwestern end of the Laptev Sea; Tiksi near the delta of the Lena River; Kresty on the Kolyma River; and Ambarchik and Pevek at the southern part of the East Siberian Sea.

The route is open up to 150 days per year with the aid of icebreakers and the melting of fast ice by means of dark powder sprinkled on it. Two

new nuclear-powered icebreakers of the Lenin class are to be added in the early 1970's; they are expected to prolong the shipping season to about six months.[90] The route is now also open to foreign commerce on payment of a fee for icebreaker and pilot services.

The Northern Sea Route is of economic and strategic importance to the U.S.S.R. Freighting is estimated at 1.5 to 2 million metric tons, carried by 200-300 ships.[59] Most freighting is not a through trip, but rather from Murmansk to destinations on the eastern portion of the route. Ships engaged in local traffic are often able to make two to three round trips a season. The major freighting item is timber exported from Igarka on the Yenisey (reaching 188,000 standards in 129 ships in 1967)[59] Next is probably bringing general freight to Dudinka (for Norilsk) and to Pevek and the Kolma River for mining settlements inland. The through route from west to east is used to transfer Navy ships such as cruisers, destroyers, and submarines to and from bases in the Far East.

A.4.5.4 Air Routes

The major air routes in the U.S.S.R. arctic are shown in Figure 38. [90, 70, 89] The larger cities such as Murmansk, Archangel, Vorkuta, and Norilsk have scheduled air service. Airlines, following the major rivers, generally link all the main towns and mining centers. Special airlifts are common in more important research areas.

A.4.5.5 Pipelines

Figure 39 shows the principal U.S.S.R. gas fields and pipelines. [69] A 48-inch diameter gas pipeline connected the Vuktyl gas field in western Siberia to the Moscow-Leningrad gas transmission system in 1969. [69] By the late 70's the west Siberian gas may be handled by transmission mains of 80-inch and 100-inch lines to European Russia, the Baltic area, Belorussia, the Urals, and the Ukraine and to countries of Eastern Europe. [69]

In eastern Siberia the natural gas field at Tas-Tumus is connected to Yakutsk via a 250-mile-long pipeline to fuel a gas-turbine power station. The pipeline has been extended to the Bestyakh-Pokrovsk area for supplying gas to cement and lumber plants.

Another gas pipeline is the 170-mile line built eastward across the Yenisey River to the mining center of Norilsk.

In all, 39,000 miles of pipelines have been built to carry gas from the remote areas. Additional pipelines are planned, and the western Siberia throughput is expected to more than double by 1975. [72] It has recently (April 1971) been reported that Belgium may join three other west European countries as importers of Siberian natural gas. Austria, Italy, and West Germany are expected to begin receiving pipeline deliveries from Russia in 1973, and Belgium may extend the line from West Germany. [92] Soviet officials contend that the large-diameter pipelines can deliver Siberian gas to the Moscow area at one-third the cost of bringing in coal by railroad. [83] They also contend that west Siberian crude oil, even in the first stages of development, including high capital outlays, will cost about the same as

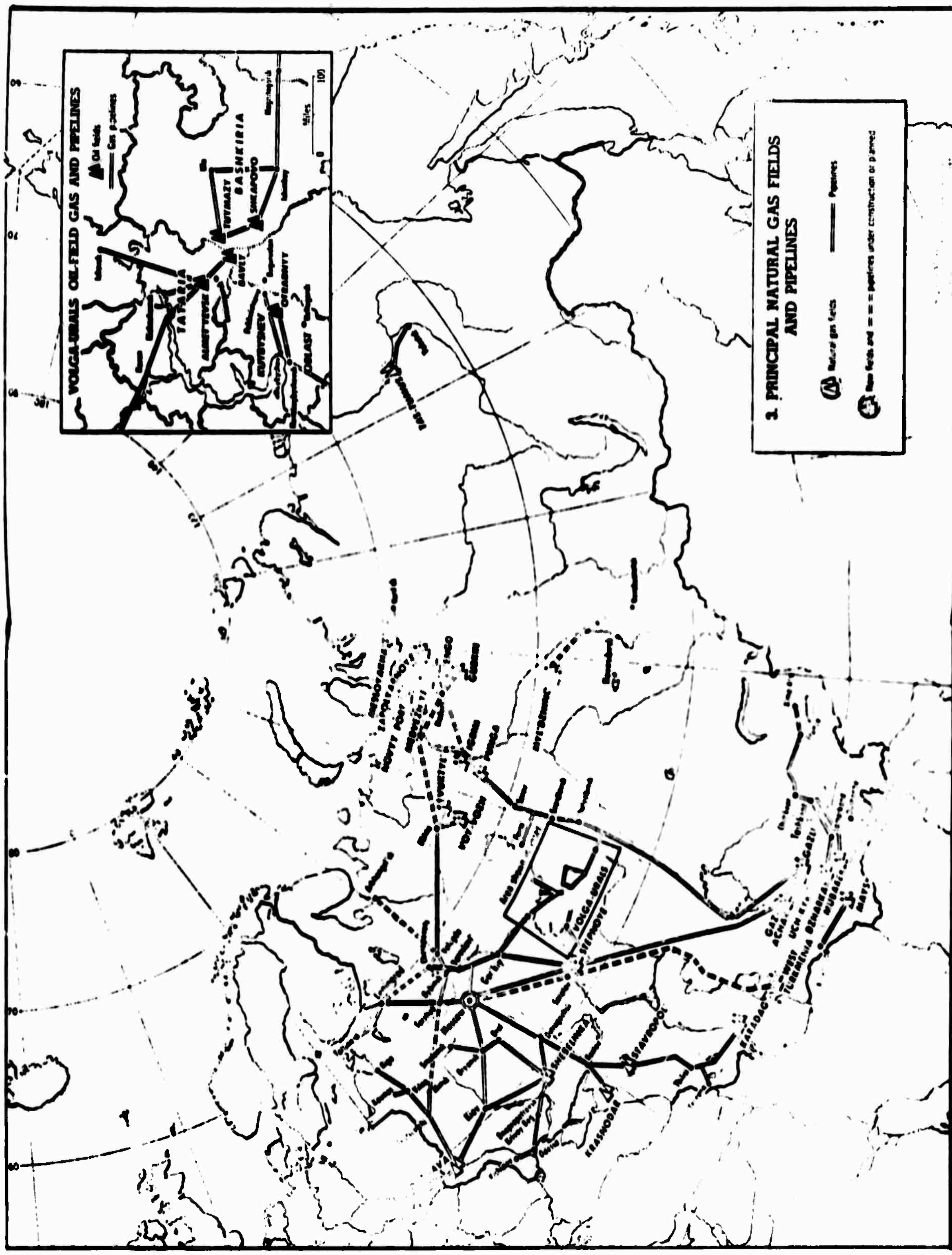


FIGURE 39 PRINCIPAL NATURAL GAS FIELDS AND PIPELINES

Volga-Ural oil, which is the cheapest obtainable now. [83]

The U.S.S.R. has about 18,000 miles of oil pipelines. [76]

A.5 SCANDINAVIAN ARCTIC RESOURCES

Arctic Scandinavia, if it were defined as the Scandinavian areas nortn ot 60^{O}, would embrace nearly all of Norway, Sweden, and Finland, plus all of Greenland and Iceland. If the Arctic Circle is used as the boundary, most of Sweden, Norway, and Finland fall south of the boundary and all of Iceland, and a part of southern Greenland also become non-arctic. If the criterion used is not a parallel of latitude but an area with "arctic conditions", primarily determined by water navigation conditions and accessability, the only parts of Scandinavia that are actually "arctic" are large parts of Greenland and Svalbard. Sweden, Finland, and Norway are in effect sub-arctic in parts and otherwise are temperate zone areas; made so by the Gulf Stream. However, for purposes of this study the areas north of the Arctic Circle will be given attention as arctic areas.

A.5.1 Norway

Figure 40 shows the towns, railroads, and motor roads of arctic Scandinavia, including parts of Norway, Sweden and Finland. The Norway area is generally mountainous, with an elevated coast strongly dissected by fjords and inlets. The coast and ports are ice-free.

Most of the population is concentrated in small towns along the coast or at the base of the fjords. About 100, 000 of Norway's total population of 3. 7 million live in North Norway. Three towns, Bodø, Narvik, and Tromsø have populations above 10, 000.

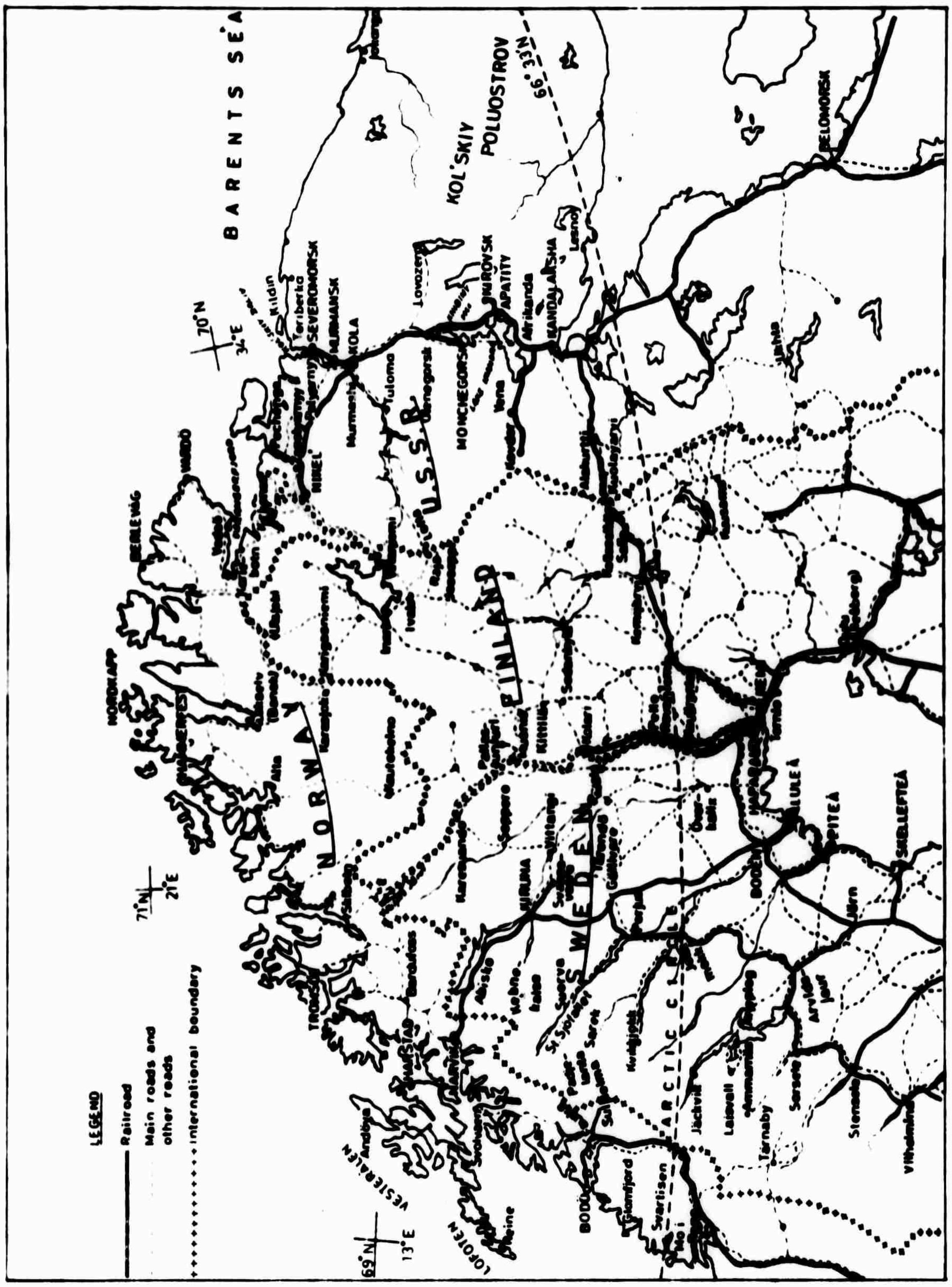


FIGURE 40 MAP OF ARCTIC SCANDINAVIA AND THE KOLA PENINSULA

A.5.1.1 Mineral Resources

Aside from the fisheries off the coast, the major products of north Norway are minerals, of which iron ore is the most significant. Norway's largest mine is located just south of Kirkenes, at the Norwegian-Soviet border on the Barents Sea. The mine produces about 2.5 million tons of iron concentrates per year. [90] Reserves are estimated at about 500 million tons of low grade ore. The concentrates are shipped from Kirkenes port, mainly to smelters in western Europe. A much greater quantity of iron ore is shipped from the port of Narvik, which receives the ore via railroad from the richer north-Sweden mines. The rail-port capacity is 20 million tons per year.

At Sulitjelma, close to the Swedish border, there is a mining center producing copper concentrates and pyrites. The nearby port of Bodø serves as a shipping point.

Like the other Scandinavian countries, Norway has been considered poor in energy minerals. The only resource of even local consequences has been the coal on Svalbard. Production there has ranged upward of 450,000 tons annually, but 1968 production was down to 330,000 tons. [93] Recently the Norwegian energy-resource picture has changed, due to the discovery of important oil resources by a Phillips consortium in the Norwegian sector of the North Sea. The so-called Ekofisk find is about to begin production from a field which is 150 miles off the southwest Norwegian coast. The field's potential has been estimated as more than 1 billion barrels. [94] The Ekofisk find is not in the Arctic, but the find has spurred anew the exploration in the Norwegian continental shelf areas between 62° and 83° which includes

Svalbard (the Spitsbergen Archipelago). Exploration has previously been conducted in the Spitsbergen area by U.S., Norwegian, Soviet, and French concerns since 1960, thus far without success. Soviet interests have also operated coal mines on what, until recently, was called West Spitsbergen (See Figure 41, map of Svalbard)

A.5.1.2 Transportation

Motor roads connect all major towns on the mainland of north Norway. Roads also connect to southern Norway, to northern Finland, and, via Finland, to Sweden. A railroad extends from southern Norway to Bodø and the mining area of Sulitjelma, but does not reach the Narvik-Tromsø-Hammerfest-Kirkenes towns farther north. Narvik is connected by rail to the iron mines in northern Sweden. Airports exist at Kirkenes, Lakselv, Hammerfest, Alta, Kautokeino, Tromsø, Bardufoss, Harstad, Narvik, Svolvaer, Ballstad, and Bodø. Coastal steamers make daily calls at all the larger and most of the smaller port towns from Bodø around North Cape to Kirkenes.

Meteorological stations are located on the Norwegian island of Jan Mayen, 300 miles northeast of Iceland, and on Bear Island, located between North Norway and Spitsbergen.

A.5.2 Sweden

One-seventh of Sweden lies north of the Arctic Circle. All the area is inland, with mountains to the north and west. The largest town is the iron

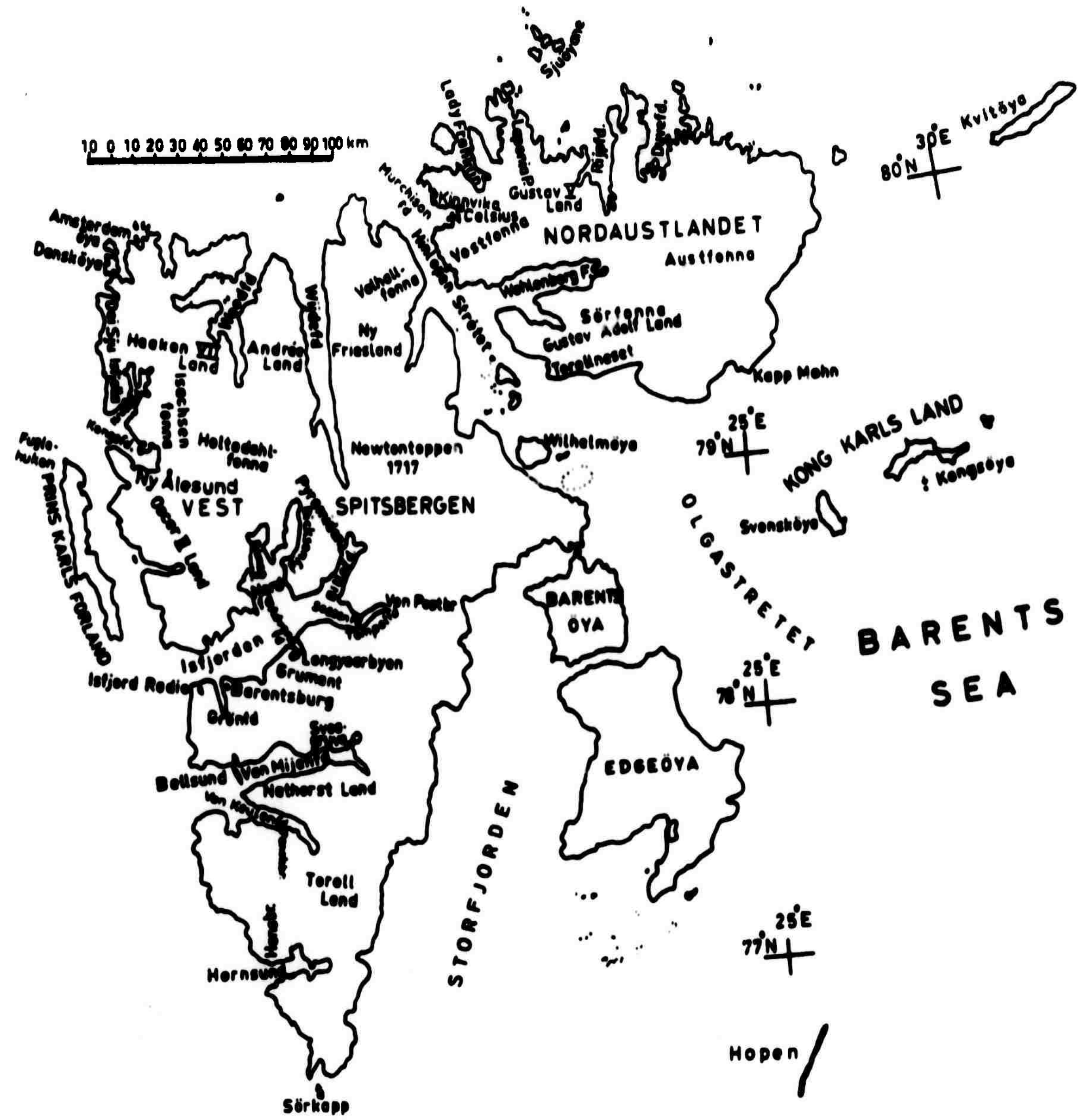


FIGURE 41 MAP OF SVALBARD, EXCLUDING BJORNOYA

district town of Kiruna, with a population of 28,000. The permanent population of arctic Sweden is estimated at 80,000, of a national total of nearly 8 million. An ESRO Sounding Rocket Launching Range has been active near Kiruna since 1966. It is operated by the European Space Research Organization.

A.5.2.1 Minerals

The principal mineral resource of arctic Sweden is iron ore, which has been mined actively since 1888. Estimated reserves are 3,000 million tons.[94] Ore fields are concentrated around Kiruna, Gallivare, and Malmberget. Total capacity of the pelletizing plants in these areas is 4.4 million tons per year. Most of the iron-rich ore is exported - 25 million tons in 1968. Northern Sweden also has copper resources, recently being developed. In 1968 the Boliden Company opened an open-pit mine at Aitik, 10 miles southeast of Gallivare. The 1968 production was 18,200 tons of metal content ore. Production is scheduled to reach 2 million tons per year, which will yield 20-35 tons of concentrate, and 10,000 tons of recoverable copper.[95] Total reserves are estimated at 30 million tons open-pit, and 120 million tons additional underground to a depth of 300 meters. The metal ore is said to extend to a depth of 600 meters (nearly 2000 feet).[95]

A.5.2.2 Hydroelectric Power

There are several hydroelectric power plants in arctic Sweden, including those at Porjus and Harspranget. The economic hydroelectric

potential of the area is estimated at 14,600 million kilowatt hours per year. (90) A one million kilowatt station is planned near the Norwegian border, in the vicinity of Narvik.

A.5.2.3 Transportation

Two Swedish railroads penetrate the Sweden arctic - the Malmbanen railroad, which opened in 1888, and extends to the Norwegian port of Narvik, and the Inland railroad, which connects with southern Sweden. Good motor roads link the towns in the eastern half of arctic Sweden and connect with those to the south and to Finland. Kiruna has regular air service to southern Sweden.

A.5.3 Finland

One-quarter of Finland is located north of the Arctic Circle. Most of the area is lowland. The major town, Rovaniemi, which is actually just south of the Circle, has a population of about 25,000. Lesser towns are Kemijarvi, Ivalo and Sodankyla. Arctic Finland has about 50,000 people, out of a total population above 4.5 million.

A.5.3.1 Minerals

Iron ore mining is an important industry in arctic Finland. Mines are located in the region of Kemijarvi and Kolari. Cobalt and gold have been found in the Kittila region, and limestone is found near Kolari. (96) Finland lost

[illegible] U.S.S.R. [illegible] World War II.

A Finnish company is developing a new iron deposit in the Kolari district and plans to begin production in [illegible]. Finnish Lapland also has some apatite deposits. [illegible]

[illegible] Hydroelectric Power

The Finnish sector area has potential for the generation of hydroelectric power, and a proposed net would provide 5,100 million kilowatt hours annually. [illegible]

[illegible] Transportation

One railroad extends from Rovaniemi through the mining areas of Kemijarvi and then on to the U.S.S.R. border, where it connects with the Kola Peninsula Soviet rail network. A second railroad extends from southern Finland to Kolari, and Rovaniemi also has a rail connection with Oulu and points farther south. Motor roads connect all Finnish towns and there are five road connections with Sweden, three with Norway, and four with the U.S.S.R. Rovaniemi and Ivalo have airline service with Kirkenes at the eastern tip of north Norway and with Helsinki, in southern Finland. Connections with Murmansk have also existed.

A.5.4 Greenland

Greenland, which is constitutionally a part of Denmark, has the northernmost land in the world, with Coffee Cap Island at 83°38' N, 33°52' W. Eighty-four percent of Greenland is covered by a dome-shaped ice cap, as is shown in Figure 42 (96) Most of Greenland is above the Arctic Circle and has arctic conditions, with only 16 percent of the land ice free. (97) Most of the population - 40,000 of the total of about 50,000 - lives along the southwest edge of the island, where the warmer ocean currents moderate the climate.

A.5.4.1 Transportation

Conventional roads between towns do not exist in arctic Greenland, and special snow vehicles are used for military transport on the ice cap. Shipping along the east coast is limited by ice conditions to a short summer season. However, the west coast season is much longer for all shipping. Several airfields exist: at Thule Air Base in Northwest Greenland, Sonore Stromfjord (Sonderstrom) on the west coast, Nord at the Arctic Ocean, Mestersvig on the east coast, and Godthaab and Julianehaab on the southwest coast, The world's longest commercial helicopter routes are maintained between Sondrektoven, Goothaab and Sukkertoppen.

A.5.4.2 Minerals

<u>Cryolite</u> has been mined in southwest Greenland at Ivigtut for over a century. At one time the production was of major economic importance, with

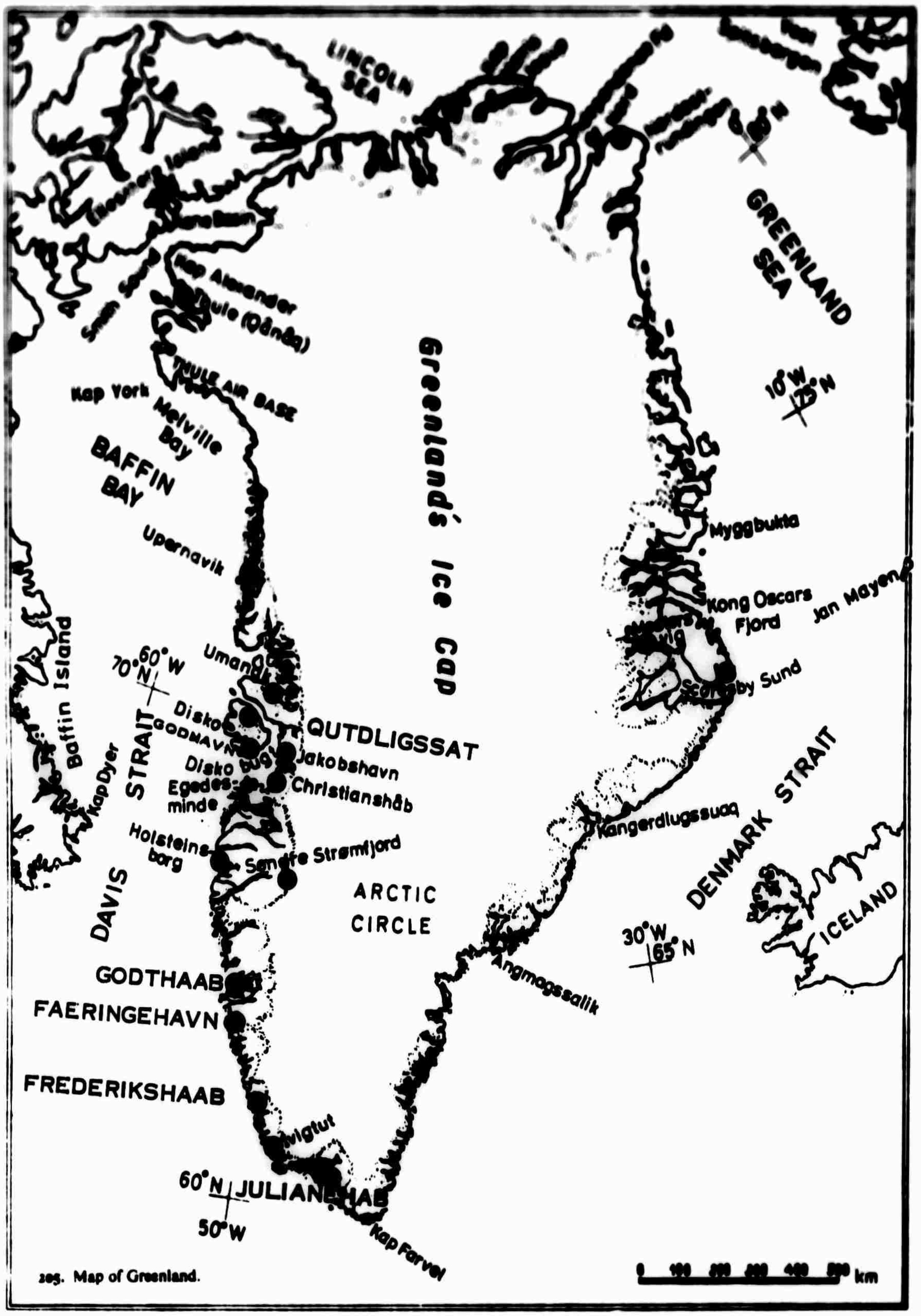


FIGURE 42 MAP OF GREENLAND

exports around 40-50 thousand tons per year.[90] The mine is now closed, however. It is the only place in the world, aside from the U.S.S.R., where a large deposit of the mineral has been found. Its main use is as a flux in the electrolysis process of aluminum smelting.

However, Greenland has not lost its interest as a potential source of valuable minerals. As may be noted Greenland is by far the largest unexplored land mass in the world that is politically stable.[98] Its geologic, climatic and logistic characteristics are similar to much of arctic Canada, and it is not too difficult to explore. The recently organized Geological Survey of Greenland (GGU) has set out to map the country and to advise the Danish Government on minerals policy. The entire island has now been mapped. Prospecting will follow on much of the 185,000 square miles that are uncovered coastal region. The minerals most anticipated are oil, gas, lead and zinc. A small lead-zinc deposit was, in fact, profitably mined in the early 1950's near Mesters Veg on the east coast. Inland from there a large molybdenum deposit was discovered. On the west coast a small amount of low-grade coal has been mined from time to time.

Exploration during the past ten years has been mainly under Canadian consortiums. Cominco, Ltd., controls a lead-zinc deposit on the west coast. A production decision is anticipated by 1975.[98] Another Canadian company (Renzy Mines) has a 2,000 square mile concession at Fiskenaesset, on the southwest coast, which is being examined for copper-nickel-platinum sulphide mineralization. Low grade chromite, which carries vanadium and rutile, has also been found in the area. Possibilities of nickel, magnelite, kimerlite, and fluorite, have also been reported. A Danish company has

a large concession on the east coast, embracing a molybdenum discovery. A low-grade uranium mineralization on the south tip of Greenland is also being investigated.

The most recent intense interest has developed in the off-shore areas along the west coast,were non-exclusive exploration concessions have been granted for limited terms of years. The search is for oil and gas, and also for radioactive materials. A Canadian consortium is reported to be spending $2.3 million in oil exploration in northern Greenland in 1971.[99] The oil company interest reportedly centers on the waters off west Greenland, all the way from the northeast corner of Baffin Bay (Thule Area) into Labrador Sea off Cape Farvel at the southern tip of Greenland.[100] U.S. and European companies have flown aero-magnetic surveys,and seismic surveys have been made by two U.S. companies.[100] There are 19 companies holding licenses and Activity has been spurred by the explorations begun in 1969 in the Canadian Arctic archipelago and by the Baffin Bay geophysical investigations. The Danish Government has not yet decided on granting exclusive exploration or exploitation rights. A committee has been drawing up recommendations to the Government.

The ultimate result of the current activities off the west coast cannot yet be forecast. Drilling is said to be at least three or four years away. A one-year delay in the award of concessions is anticipated, and 1974 is the earliest target date for drilling.[101] Weather, wind, fog, and ice are pointed to as negative factors which will also increase costs. Until more is known about the potential oil and gas trapped in the area, one can only note that the degree of oil company interest suggests the possibility of further great petroleum finds in the Greenland - Eastern Canada region

of the Arctic. The Alaskan, north Canadian, and Siberian oil resources that are assuming such great potential importance, may be found to extend also into the Greenland - northeastern - Canada area.

A.6 ESTIMATE OF FUTURE SIGNIFICANCE OF ARCTIC RESOURCES

A.6.1 The Less Promising Arctic Resources

If people are a significant resource, the Arctic gives little promise of developing that resource in great quantity. The foregoing references to arctic-area populations have simply emphasized the well-known fact that those areas, with few exceptions, are very thinly populated. Large-scale resource development may change this situation to some degree, but it appears now that the most probable types of new economic activity in the Arctic for the next few decades will be precisely those that will require little manpower. Migration to the Arctic of many people for other purposes cannot now be foreseen.

Agriculture is now a distantly minor activity in most arctic areas, and relative costs-of-production factors, probably much more than higher transportation costs, are unlikely to change the picture.

Forest resources are absent, or nearly so, from nearly all the genuinely arctic areas, although the Arctic Circle is not in all circumpolar areas north of the tree line. Nevertheless, the relatively slow growth of trees in the forested arctic areas, the higher costs of production and transportation in most arctic places, and the fact that forests are a renewable resource at lower cost in lower latitudes, are among the important factors that point to very minor forestry development in most of the Arctic.

Industry, except for specialty industries encouraged by the presence of a suitable resource, is not now predictable for much of the Arctic.

Aside from native crafts, the cost factor again is discouraging, as is the labor supply now and probably in the future. Efforts by the Soviets and others to attract or force labor into the high arctic have had some, but not major successes.

The fishing industry is a widespread and, in some waters, relatively lucrative activity in the Arctic. It is yet to be established, however, that the Arctic Ocean is teeming with edible fish, and most of the present fish catch, except for example in the Gulf Stream waters north of Norway and the western U.S.S.R., is in the somewhat warmer waters south of the Arctic. The fishing industry prospects for most of the Arctic must probably be rated as unpromising.

A.6.2 Arctic Resources of Possible or Likely Economic or Strategic Significance

The circumpolar, country by country, survey has indicated the presence of considerable deposits in the arctic of numerous hard minerals, including metals. It has also been noted that while some of the hard minerals are now being produced in the Arctic, and that production in most arctic areas is on the rise, the picture is not uniform. High production costs, labor scarcity, transportation problems, and, in general, lower costs of production outside the Arctic must give rise to caution in predicting sharp increases in hard metal production across the board in the arctic deposits. Heavy world demands may have the effect of raising prices on some minerals to the point where arctic production becomes profitable. Copper may well become such a mineral, and copper deposits of greater or lesser amounts have been located, if not yet developed, in circumpolar

areas such as Alaska, Canada, Scandinavia, and the U.S.S.R. iron ore deposits, if accessible, and rich enough in iron, may also be found worthy of development. The Mary River deposit on Baffin Island is a good example of an extensive, rich, ore deposit. The predicted cumulative demands for iron and steel in the U.S. for the next three decades indicate, as stated, that the known reserves are 40 percent short, and that the supply will need to be augmented. It is unlikely, under these circumstances, that the 139 million tons of Baffin Island iron ore which grades 68 percent iron or better, will be left in the ground. Soviet deposits at Olenegorsk, with even greater total reserves will probable also be developed, although the Soviet iron ore production is now concentrated in the Ukraine and other non-arctic areas (see Figure 30). Norway and Sweden are producing, and will undoubtedly continue to produce, from their northern iron mines, but conditions there are not really arctic, and the transportation problem is a simple one, due to the ice-free ports of Narvik and Kirkenes close at hand.

Other minerals that may well develop more critical supply and demand situations have also been noted, such as mercury, lead and zinc, tin, tungsten, fluorite, and perhaps gold. The near-term prospects for significant increases in production from most arctic areas that have deposits of the named metals are not great. During the period 1980 to 2000, however, the demand curve may well cause more intense production efforts. Technological advances both in mining and in transportation techniques could also lower production and delivery costs to the point where arctic-situated mines become competitive. Again, the comparative richness of the ores becomes a factor.

In addition to the base and common metals one should also take account of rare metals that may become significant. The arctic inventory of such metals is not taken in this study.

A high U.S. official has recently stated that the U.S. demand for primary minerals will increase four-fold by the year 2000. Specifically, he predicted a six-fold demand for aluminum and titanium; a four-fold demand for tungsten and vanadium; a three-fold demand for copper, sand and gravel, beryllium, fluorine, tantalum, and magnesium; and a doubling of demand for many others.[18] Even if his prediction is borne out, the prospect that many of the arctic area mineral deposits will lie undeveloped does not entirely disappear, but for some key metals major development may well occur if the projection is moved to the year 2000.

A.6.3 Arctic Resources Likely to be of Major Significance - Energy Fuels

A.6.3.1 Presently Known Resources and Consumption Rates

Although we have noted coal deposits in Alaska, arctic U.S.S.R., and in a few other arctic locations, the prospect that arctic coal will become a critical energy resource to be developed in the next three decades appears to be extremely dim. The fact that more inexpensively accessible deposits are reckoned as sufficient to meet world needs for upward of 400 years is likely to offer little prospect for major arctic production. A reservation should be made, however, that a country such as Japan, greatly in need of energy fuels, may find it advantageous to bargain for the production of some coal from easily accessible Alaska, just as Norway has produced some coal in Spitsbergen.

The energy source which has risen most sharply in world production and consumption has its location in the deposits of oil and gas that have been found in great and small concentrations in all continents and in many parts of the coastal seabeds. The rise in world production and consumption will be seen from Tables 10, 11 and 12, 13.(82) It will be noted that world oil production has increased, during the period 1959-1969, from slightly over one billion tons a year to over two billion (1,012.2 million to 2,145.0 million). During the same period, consumption, naturally, has also doubled, going from 20.07 million barrels per day to 42.55 million barrels. The rate of increase, both in production and consumption, during that period has been greater in the Eastern Hemisphere than in the Western, both production and consumption having tripled in the Eastern Hemisphere during the decade.

Table 14 shows would "published proved" oil reserves at the end of 1969.(82) Figure 43 shows the relative production on a regional basis, and the world total for the decade 1959-1969, as well as the world reserves at the beginning and end of that decade.

Several facts of interest to the evaluation of potential arctic reserves as a factor in the energy picture during the coming decades emerge from the recent production and reserve tables. It should be noted at the outset that the statistics given are either recorded historical facts, in the case of production figures, or, on the "reserves" side are of "published proved" reserves only. On the other hand, most of the

World Oil Production

Table 10 — MILLION TONS

COUNTRY/AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Yearly Change [illegible]	[illegible]
NORTH AMERICA													
U.S.A.													
Crude Oil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Natural Gas Liquids	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Canada	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mexico	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL NORTH AMERICA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CARIBBEAN													
Venezuela	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Colombia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Trinidad	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL CARIBBEAN AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SOUTH AMERICA													
Argentina	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Brazil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Others	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL SOUTH AMERICA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL WESTERN HEMISPHERE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WESTERN EUROPE													
France	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
W. Germany	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Austria	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Others	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL WESTERN EUROPE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MIDDLE EAST													
Iran	40.4	52.6	50.4	56.0	73.1	85.4	90.0	105.1	120.3	142.2	160.1	+13.0%	+14.5%
Iraq	41.6	47.5	46.6	49.3	50.2	61.2	64.4	60.0	60.1	70.3	70.0	+6.0%	+4.0%
Kuwait	69.5	81.0	82.7	92.2	67.2	106.2	100.0	114.4	115.2	121.1	129.5	+6.5%	+4.0%
Neutral Zone	0.1	7.3	6.5	13.0	18.3	18.0	19.1	22.3	21.7	22.1	23.3	+18.3%	+4.5%
Qatar	7.0	8.2	8.3	8.8	9.1	10.2	11.0	10.6	15.4	16.3	17.0	+8.3%	+10.5%
Saudi Arabia	54.2	62.1	69.2	75.0	76.5	86.2	100.0	110.4	120.7	140.0	140.0	+10.5%	+11.5%
Abu Dhabi	—	—	—	0.8	2.0	8.0	13.6	17.3	18.3	24.0	28.0	*	+26.3%
Others	2.1	2.2	2.2	2.2	2.4	2.5	2.8	3.3	6.5	17.2	24.0	+25.3%	+57.0%
TOTAL MIDDLE EAST	226.0	261.0	280.3	300.0	330.3	380.5	415.5	460.0	466.7	500.1	618.3	+10.5%	+10.3%
AFRICA													
Algeria	1.2	8.8	15.0	20.7	23.0	26.5	26.5	30.0	30.1	42.0	44.6	+63.5%	+11.0%
Libya	—	—	0.6	0.7	22.4	41.4	58.2	72.3	84.3	125.5	140.0	*	+29.5%
Other North Africa	3.3	3.4	3.0	4.0	8.8	8.0	8.0	2.0	8.6	10.6	10.0	+10.5%	+24.5%
Nigeria	0.5	0.6	2.0	3.5	3.0	8.0	13.2	20.7	18.2	8.0	20.0	+40.0%	+34.0%
Other West Africa	0.0	0.3	1.0	1.5	1.0	2.4	1.0	2.3	4.1	8.2	11.0	+31.0%	+37.0%
TOTAL AFRICA	5.8	13.6	24.4	30.2	57.7	82.6	107.3	136.1	152.3	196.0	252.3	+40.5%	+25.0%
SOUTH EAST ASIA													
Indonesia	18.1	20.6	21.4	23.1	22.5	23.3	23.0	23.5	25.6	29.2	35.3	+8.3%	+8.5%
Other S.E. Asia	5.4	4.6	4.2	4.0	4.0	3.0	3.6	4.7	5.0	6.2	6.8	+2.5%	+13.0%
TOTAL SOUTH EAST ASIA	24.5	25.2	25.6	27.1	26.5	26.6	27.7	28.2	31.1	35.0	42.2	+5.5%	+6.5%
U.S.S.R.	126.5	147.6	166.0	166.0	206.1	223.6	242.0	265.1	288.0	309.0	326.0	+8.8%	+8.0%
EASTERN EUROPE AND CHINA	17.2	18.3	20.6	21.0	22.4	24.2	25.2	26.7	27.0	29.7	30.6	+5.0%	+4.5%
OTHER EASTERN HEMISPHERE	1.7	1.6	2.0	3.1	3.5	4.2	5.1	7.0	8.2	8.7	11.4	+21.0%	+22.0%
TOTAL EASTERN HEMISPHERE	420.6	485.1	535.1	602.6	673.6	763.6	845.6	940.0	1,025.1	1,162.4	1,301.6	+12.0%	+11.3%
WORLD (excl. U.S.S.R., E.Europe, China)	865.5	923.3	978.3	1,053.7	1,124.1	1,212.6	1,296.2	1,404.1	1,506.5	1,601.7	1,787.0	+7.5%	+6.0%
WORLD	1,012.2	1,090.5	1,162.3	1,261.5	1,352.6	1,460.7	1,564.4	1,695.6	1,821.5	1,990.4	2,145.6	+7.6%	+8.0%

*Greater than 300%

Table 11

THOUSAND BARRELS DAILY

COUNTRY/AREA	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Yearly Change 1969 over 1968	Yearly Change 1969 over 1964
NORTH AMERICA													
U.S.A.													
Crude Oil	7,055	7,035	7,185	7,330	7,540	7,615	7,805	8,295	8,810	9,095	9,215	+ 2·6%	+ 4·0%
Natural Gas Liquids	880	930	990	1,020	1,100	1,155	1,210	1,265	1,410	1,505	1,590	+ 6·0%	+ 6·5%
	7,935	7,965	8,175	8,350	8,640	8,770	9,015	9,580	10,220	10,600	10,805	+ 3·3%	+ 4·3%
Canada	520	540	645	735	790	850	935	1,015	1,110	1,195	1,325	+ 6·6%	+ 6·3%
Mexico	275	300	320	335	345	355	360	370	410	435	455	+ 5·3%	+ 5·3%
TOTAL NORTH AMERICA	8,730	8,805	9,140	9,420	9,775	9,975	10,310	10,965	11,740	12,230	12,565	+ 3·0%	+ 4·8%
CARIBBEAN													
Venezuela	2,770	2,845	2,920	3,225	3,270	3,395	3,505	3,400	3,575	3,640	3,840	+ 2·8%	+ 1·5%
Colombia	145	150	145	140	165	170	200	185	190	175	210	+ 3·8%	+ 4·5%
Trinidad	110	115	125	135	135	135	135	150	180	185	160	+ 3·8%	+ 3·3%
TOTAL CARRIBEAN AREA	3,025	3,110	3,190	3,500	3,570	3,700	3,840	3,745	3,945	4,000	4,010	+ 2·0%	+ 1·6%
SOUTH AMERICA													
Argentina	125	175	230	270	270	275	270	285	315	345	355	+11·0%	+ 5·3%
Brazil	65	80	95	95	105	90	95	115	145	185	170	+10·3%	+13·5%
Others	80	90	95	105	110	115	120	120	140	160	155	+ 8·8%	+ 5·8%
TOTAL SOUTH AMERICA	270	345	420	470	465	480	465	520	600	670	680	+ 8·0%	+ 7·3%
TOTAL WESTERN HEMISPHERE	12,025	12,260	12,750	13,390	13,630	14,155	14,635	15,230	16,285	16,900	17,275	+ 3·8%	+ 4·0%
WESTERN EUROPE													
France	30	40	45	50	50	55	60	60	55	55	50	+ 4·5%	− 2·5%
W. Germany	100	110	125	135	150	150	160	155	155	160	155	+ 4·5%	+ 8·5%
Austria	50	45	45	45	50	50	55	55	55	55	55	+ 1·5%	+ 0·0%
Others	95	105	115	120	125	160	160	165	180	165	200	+ 8·8%	+ 4·0%
TOTAL WESTERN EUROPE	275	300	330	350	375	415	435	435	445	455	460	+ 5·3%	+ 1·8%
MIDDLE EAST													
Iran	940	1,060	1,195	1,330	1,475	1,710	1,905	2,110	2,595	2,850	3,375	+13·0%	+14·5%
Iraq	850	955	990	995	1,160	1,255	1,315	1,360	1,225	1,510	1,525	+ 0·0%	+ 4·8%
Kuwait	1,380	1,620	1,645	1,630	1,930	2,115	2,170	2,275	2,290	2,428	2,575	+ 8·5%	+ 4·0%
Neutral Zone	120	135	175	245	315	360	355	420	420	425	450	+14·3%	+ 4·5%
Qatar	160	175	175	190	195	215	230	290	320	340	355	+ 0·3%	+10·5%
Saudi Arabia	1,100	1,245	1,390	1,525	1,630	1,730	2,025	2,395	2,600	2,830	2,995	+10·5%	+11·5%
Abu Dhabi	—	—	—	15	55	185	280	360	380	500	600	*	+28·3%
Others	50	45	45	45	45	50	60	65	130	340	400	+25·3%	+57·0%
TOTAL MIDDLE EAST	4,600	5,235	5,615	6,175	6,605	7,620	8,340	9,306	8,960	11,215	12,355	+10·5%	+10·3%
AFRICA													
Algeria	25	160	330	435	510	565	560	715	840	915	955	+43·5%	+11·0%
Libya	—	—	20	165	485	880	1,220	1,505	1,745	2,600	3,118	*	+29·5%
Other North Africa	65	65	75	80	110	130	125	130	170	290	395	+10·5%	+24·5%
Nigeria	10	20	55	70	75	120	275	420	320	140	545	+40·0%	+34·0%
Other West Africa	15	20	20	30	35	50	35	45	85	125	240	+31·0%	+37·0%
TOTAL AFRICA	115	265	500	610	1,195	1,725	2,215	2,815	3,160	4,076	5,245	+48·5%	+25·0%
SOUTH EAST ASIA													
Indonesia	360	415	430	460	455	470	480	475	515	600	715	+ 0·3%	+ 8·5%
Other S.E. Asia	110	95	60	80	80	75	80	95	115	125	140	+ 2·5%	+13·0%
TOTAL SOUTH EAST ASIA	490	510	510	540	535	545	560	570	630	725	855	+ 5·5%	+ 8·5%
U.S.S.R.	2,605	2,970	3,340	3,740	4,145	4,495	4,860	5,335	5,795	6,190	6,565	+ 9·8%	+ 8·0%
EASTERN EUROPE AND CHINA	345	385	400	440	450	465	505	535	545	595	605	+ 5·6%	+ 4·5%
OTHER EASTERN HEMISPHERE	35	35	40	65	70	85	105	140	170	195	230	+21·0%	+22·0%
TOTAL EASTERN HEMISPHERE	8,465	9,720	10,735	12,120	13,575	15,360	17,050	19,135	20,705	23,445	26,335	+12·0%	+11·3%
WORLD (excl. U.S.S.R., E. Europe, China)	17,540	18,625	19,745	21,330	22,610	24,545	26,290	28,495	30,650	33,500	36,420	+ 7·5%	+ 8·0%
WORLD	20,490	21,960	23,485	25,510	27,405	29,515	31,685	34,365	36,990	40,345	43,610	+ 7·8%	+ 8·0%

*Greater than 300%

Consumption and Trade

Table 12

COUNTRY/AREA	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Yearly Change 1969 over 1959	Yearly Change 1969 over 1968
	MILLION TONS												
CONSUMPTION													
U.S.A.	460	473	470	498	513	527	549	576	[illegible]	636	[illegible]	[illegible]	[illegible]
Canada	41	43	44	46	47	52	57	61	62	66	[illegible]	[illegible]	[illegible]
Other Western Hemisphere	79	[illegible]	86	[illegible]	92	98	102	105	112	[illegible]	126	[illegible]	[illegible]
TOTAL WESTERN HEMISPHERE	580	596	[illegible]	632	652	677	708	[illegible]	770	[illegible]	[illegible]	[illegible]	[illegible]
Benelux	17	21	24	28	32	37	41	45	46	[illegible]	54	[illegible]	[illegible]
France	25	28	31	36	42	48	54	58	66	72	80	[illegible]	[illegible]
W. Germany	27	35	41	50	66	80	88	[illegible]	98	106	119	[illegible]	[illegible]
Italy	19	24	29	35	40	48	52	58	64	[illegible]	79	[illegible]	[illegible]
U.K.	43	50	53	57	62	67	75	79	81	90	96	[illegible]	[illegible]
Scandinavia	19	21	22	25	28	31	34	39	39	45	49	[illegible]	[illegible]
Others	21	26	26	31	39	45	52	58	66	70	81	[illegible]	[illegible]
TOTAL WESTERN EUROPE	171	205	228	264	302	365	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Japan	23	30	41	49	61	75	90	99	118	[illegible]	[illegible]	[illegible]	[illegible]
Australasia	12	13	16	16	18	18	20	22	23	25	27	[illegible]	[illegible]
U.S.S.R., E. Europe, China	132	144	156	175	193	206	221	230	240	[illegible]	[illegible]	[illegible]	[illegible]
Other Eastern Hemisphere	71	77	85	90	95	[illegible]	109	118	126	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL EASTERN HEMISPHERE	411	469	526	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WORLD	991	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAIN PRODUCT DEMAND (Including Bunkers)													
U.S.A.													
Gasolines	184	187	190	197	200	212	220	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Middle Distillates	105	112	115	123	126	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel Oil	78	79	77	78	75	77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	368	379	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WESTERN EUROPE													
Gasolines	31	35	40	44	50	57	65	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Middle Distillates	47	56	62	75	90	99	113	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel Oil	66	81	93	104	121	139	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	146	173	195	220	260	295	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EXPORTS													
U.S.A.	11	10	9	9	11	11	10	10	[illegible]	9	9	[illegible]	[illegible]
Caribbean	133	136	150	150	160	167	173	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other America	8	8	11	15	18	17	18	19	30	[illegible]	30	[illegible]	[illegible]
Middle East	[illegible]	234	254	277	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
North Africa	1	9	17	30	50	71	85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
South East Asia	[illegible]	18	16	15	17	18	16	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U.S.S.R., Eastern Europe	17	26	31	35	37	42	46	50	56	[illegible]	[illegible]	[illegible]	[illegible]
Others	9	17	14	14	16	16	25	32	30	35	40	[illegible]	[illegible]
WORLD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IMPORTS													
U.S.A.	93	91	99	100	110	117	127	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Western Europe	170	206	226	265	303	342	370	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Japan	32	36	41	49	61	75	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Others	100	112	126	136	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WORLD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Consumption and Trade

Table 13

COUNTRY AREA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Yearly Change [illegible]	[illegible]
	THOUSAND BARRELS DAILY												
CONSUMPTION													
U.S.A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Canada	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other Western Hemisphere	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Western Hemisphere	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benelux	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
France	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
W. Germany	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Italy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U.K.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Scandinavia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Others	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Western Europe	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Japan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Australasia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U.S.S.R., E. Europe, China	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other Eastern Hemisphere	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Eastern Hemisphere	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WORLD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAIN PRODUCT DEMAND (Including Bunkers)													
U.S.A.													
Gasoline	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Middle Distillates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel Oil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WESTERN EUROPE													
Gasoline	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Middle Distillates	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel Oil	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EXPORTS													
U.S.A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Caribbean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other Western H.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Middle East	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
North Africa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
South East Asia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U.S.S.R. – Eastern Europe	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Others	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WORLD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IMPORTS													
U.S.A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Western Europe	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Japan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Others	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WORLD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

RESERVES

Table [illegible]

WORLD "PUBLISHED PROVED" OIL RESERVES AT END 19[illegible]

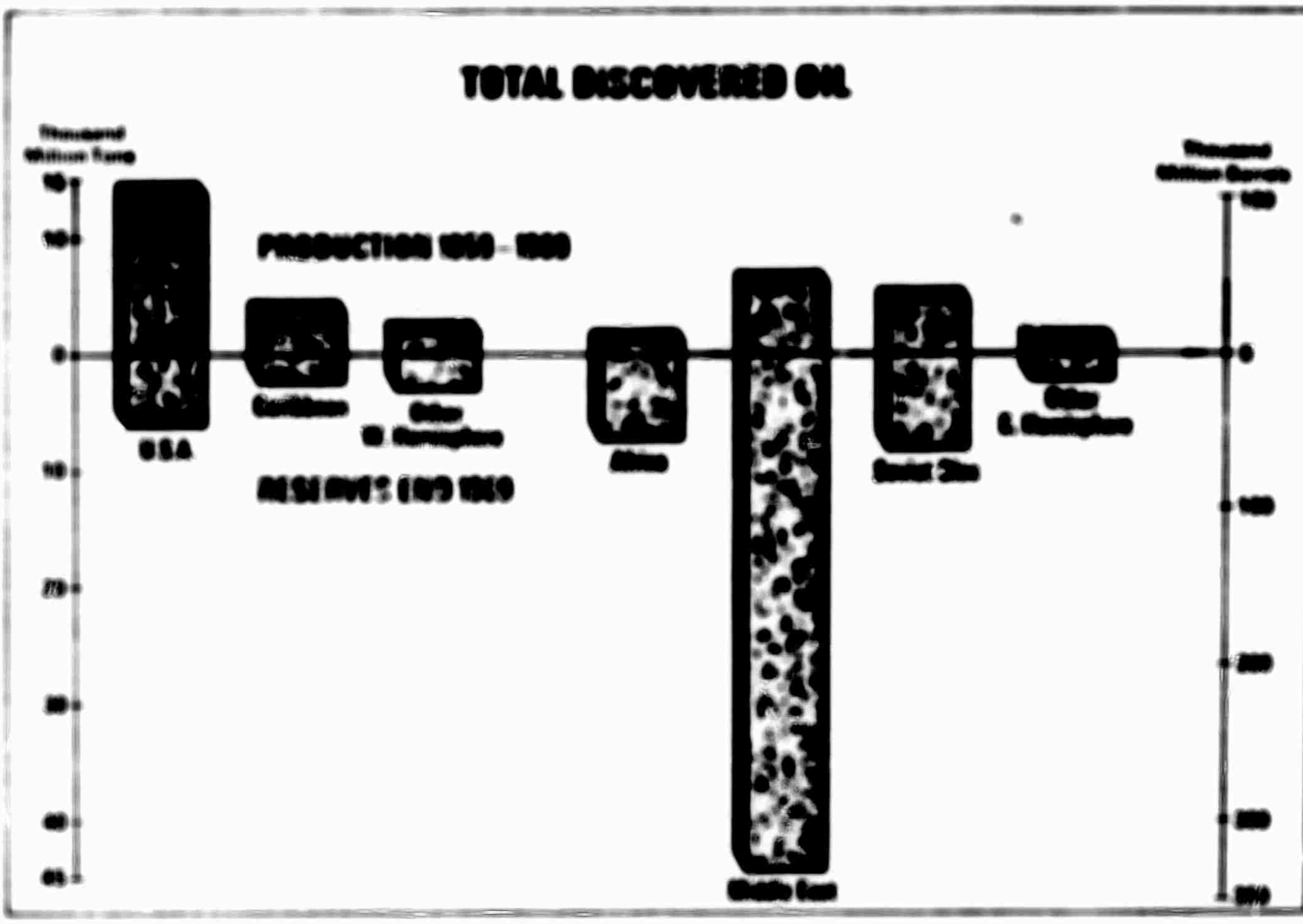
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U.S.A.	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Africa	[illegible]	[illegible]	[illegible]	[illegible]
Middle East	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WORLD	[illegible]	[illegible]	[illegible]	[illegible]

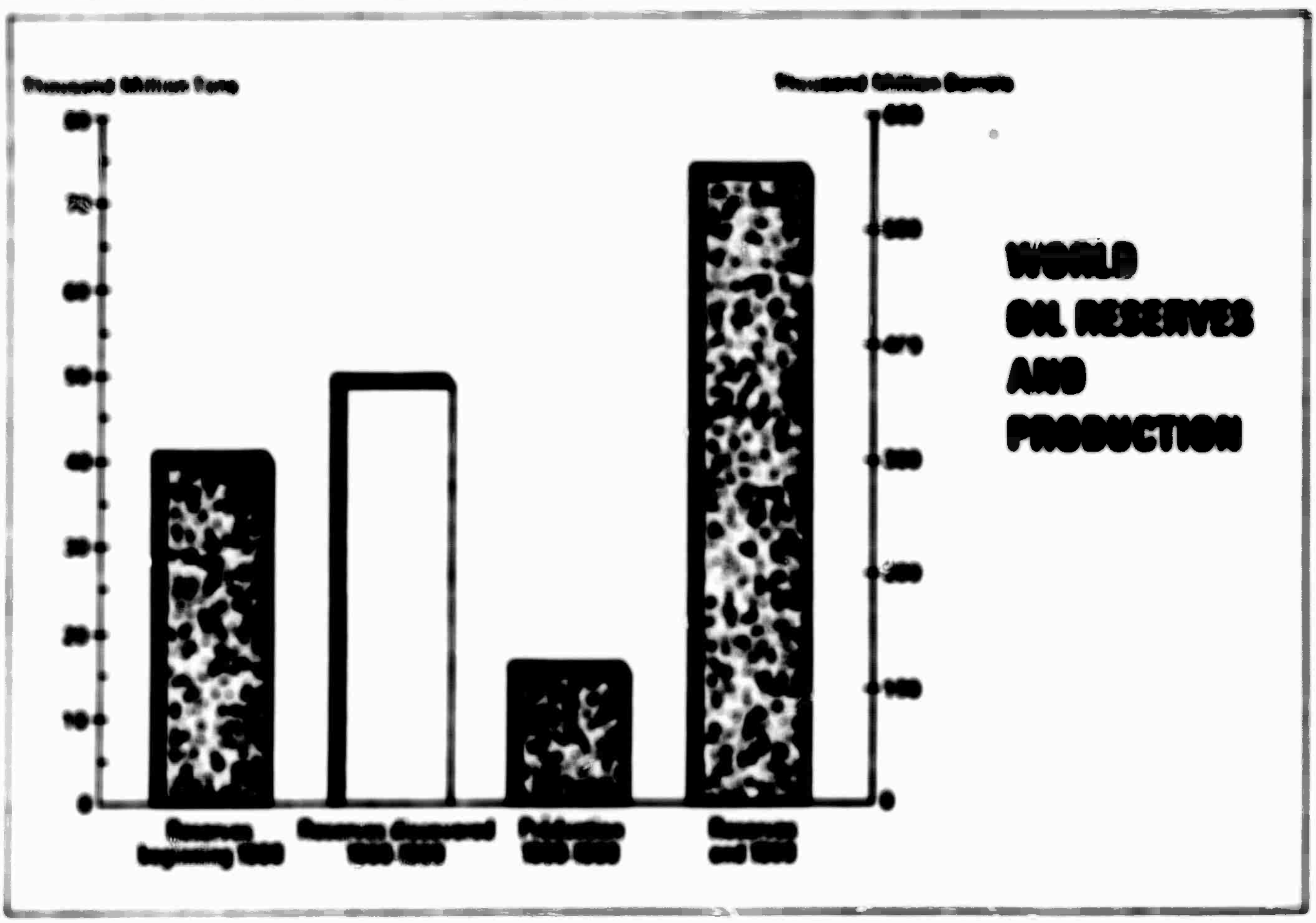
[illegible]

[illegible]

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]

Figure 43


TOTAL DISCOVERED OIL
U.S.A.


WORLD
OIL RESERVES
AND
PRODUCTION

estimates of arctic oil potential in this study have been of the estimated potential, rather than of the "proved" category.

We note, for example, that while world oil reserves increased by about 240 billion barrels during the 60's (300 billion to 540 billion) or an 80 percent increase, the increase was accounted for largely by the oil finds in the Middle East and Africa. By 1970, these two areas accounted for 72.7 percent of the world's proved reserves; whereas the U.S. had barely 7 percent, Canada less than 2 percent and the U.S.S.R. and the Eastern Europe-China area had 11 percent. In other words, the circumpolar-arctic countries, plus a number of Eastern Hemisphere countries had only about 20 percent of the world total proved oil reserves.

We note, more particularly, that the U.S., which had produced approximately 100 billion barrels of oil during the 60's, had a proved reserve of only 37.0 billion barrels at the beginning of the 70's. The U.S.-Canadian total reserves by January 1, 1970, were less than half the U.S. production during the previous decade.

We note also from the consumption tables, that by 1969 the U.S. was consuming oil at the rate of about 5 billion barrels annually. The 1970 consumption rose to 5.4 billion barrels.[102] At the 1970 rate of U.S. consumption, assuming no imports, the 37.0 billion barrel "proved" U.S. reserves of January 1, 1970, would theoretically be exhausted by the end of 1976. Assuming a continued rise in national consumption rate, the January 1, 1970 U.S. reserves would not even cover 7 years' consumption. On a similarly hypothetical basis Canada's proved reserves as of the beginning of the 70's would give 20 years' supply at the 1969 rate of consumption. The corresponding

figure for the U.S.S.R. Eastern Europe and China would be 26 years. Considering that there are economic, political, and strategic bases for any nation, particularly an industrial, technically advanced country wishing to have its own, or at least dependable, sources of energy, it is not surprising that the recent explorations and discoveries of oil in the arctic regions of the U.S., Canada, and the U.S.S.R. have aroused great enthusiasm in many quarters in each of the three countries. For example, the president of a U.S. oil company has recently estimated that the U.S. will consume 150 billion barrels of oil from 1970 to 1990, of a total world consumption of 465 billion barrels.[103] With U.S. proved reserves outside the Arctic at one-fourth his estimated requirement for the next twenty years, it was his conclusion that visible reserves were extremely low. Estimates of the future growth rate of U.S. oil consumption have varied considerably, however. The rate of increase to 1980 forecast in the Draft Environmental Impact Statement of the Department of the Interior on the Trans-Alaska Pipeline resulted in a projected 1980 U.S. annual consumption of 8.03 billion barrels. Other 1970 estimates have ranged downward to about 6.5 billion barrels. The forecast rate of increase for the decade ranged from above five percent to below three percent per year.

The potential U.S. interest in arctic gas finds is similarly related to projection consumption rates and to the known reserves with which to meet future demands. As has been noted, U.S. proved gas reserves as of January 1, 1971 were about 290 trillion cu ft. U.S. consumption in 1970 was up seven percent, to a total of 22 trillion cu ft, and provided a third of U.S. energy consumption. Again, if the 1970 rate of U.S. consumption

is applied to proved U.S. reserves, the result is only about 13 years' supply. Canadian consumption in 1969 was only 4.65 percent of U.S. consumption and Canada has been a potential source, rather than a heavy consumer of natural gas.

A.6.3.2 Summary of Potential North American Arctic Petroleum Reserves

Since a judgement concerning the potential significance of arctic North American oil and gas must depend first of all upon the potential recoverable amounts that are there, a recapitulation is in order. As has been stated, there is no universal agreement on the estimates. Probably the most clearly sustainable are the potential crude oil reserves of the Prudhoe Bay field on the North Slope of Alaska. For arctic North America the following represent estimates of reserves ranging from conservative to the most optimistic (See Figure 44).

Oil Reserves Estimates:

	Low	High
Arctic Alaska	10 bil bbls*	60 bil bbls
Arctic Canada	50 bil bbls	256 bil bbls
Arctic North America	60 bil bbls	316 bil bbls

*Included in 1970 proved reserves

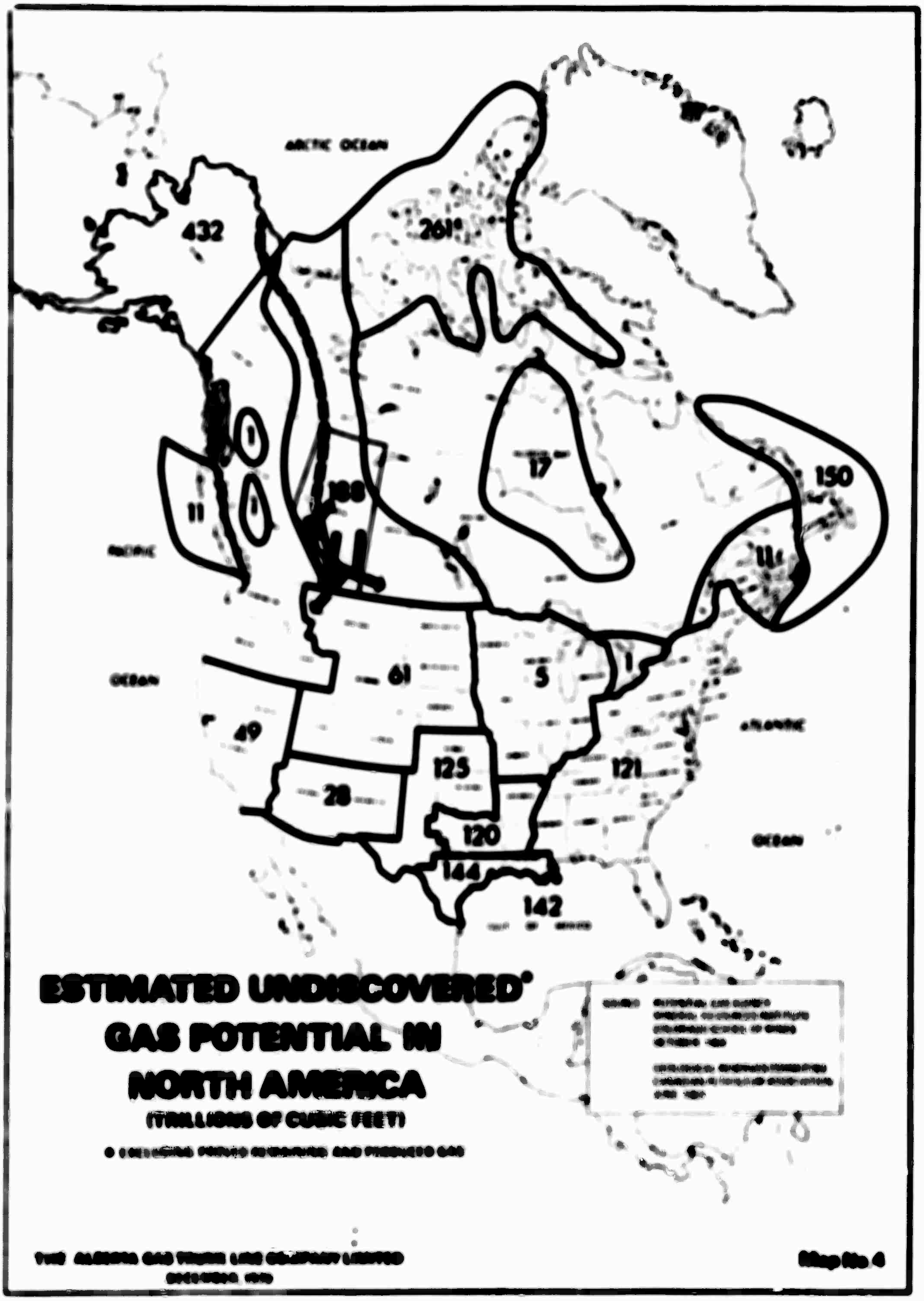

ARCTIC OCEAN
432
261*
188
150
17
11
61
5
1
49
125
121
28
120
144
142
PACIFIC
OCEAN
ATLANTIC
OCEAN
ESTIMATED UNDISCOVERED*
GAS POTENTIAL IN
NORTH AMERICA
(TRILLIONS OF CUBIC FEET)
Map No 4

Figure 44

Gas Reserves Estimates:

	Low	High
Arctic Alaska	31 tril cu ft	432 tril cu ft
Arctic Canada	300 tril cu ft	725 tril cu ft
Arctic North America total	331 tril cu ft	1157 tril cu ft

We have noted that the U.S. plus Canadian annual rate of consumption of oil and gas as of 1970 was in the order of 6 billion barrels of oil and 23 trillion cu ft of gas. We have noted also that the 1970 proved U.S. reserves were 7 and 13 years respectively. Applying the lower estimated arctic potential reserves (331 trillion cu ft of gas and 60 billion barrels of oil) to the 1970 rate of consumption would extend the North American oil supply by eight years, and the gas supply by 14 years. On the basis of the high reserve estimates, however, the supplies would be extended by 51 years for oil and by 50 years for gas. Even assuming percentage annual rises in consumption at 3-5 percent, the higher estimates would be sufficient to cover U.S. and Canadian consumption for at least three decades. The North American arctic addition to the present total world proved oil reserves would be nearly 60 percent of that total.

A.6.3.3 Factors That May Affect the Rate of Arctic Petroleum Development

Any attempt to forecast the future significance of the truly enormous estimated petroleum reserves of the arctic region (assuming that the high estimates are justified) naturally becomes a resultant of projecting past trends and adjusting for anticipated possible and probable changes that may affect that

projection.

Looking at the past, one may note the following basic facts: [104]

1. World energy consumption has more than doubled during the 1960's.

2. Nearly all the increase has been met by oil and gas.

3. Oil is the most important fuel. This applies to nearly all countries.

4. There is a close relationship between energy consumption and the per-capita gross national product.

5. Nuclear power has not lived up to earlier promise. Technical and cost problems have retarded development.

Based largely on past, and especially on more recent trends, it has been forecast that world energy demands will increase perhaps two-fold by 1980 and three-fold before the year 2000. In recent years it has been predicted, also, that the additional energy, at least for 1970-1985 period, will be met mainly by gas and oil. However, such long-term forecasts become of dubious value unless critical evaluation is made of factors that may enter the picture to change past trends. A number of such possible factors may be noted and given some preliminary assessment. Some of the factors may become so during the 70's, and others may have a later bearing on the oil and gas demands. [104]

1. Rate of population growth may or may not be slowed.

2. The rate of economic growth in "underdeveloped" areas in terms of its effect on energy demand may be a factor, even though the growth is in turn dependent on energy input.

3. The timing of solutions to technical problems, some of them relating to more efficient utilization and recovery of energy supplies, and

especially to the problems of generating electricity economically by nuclear power, will affect the projection.

4. The rate of discovery of oil and gas, and the comparable costs of retrieval with other sources of energy will be a major economic factor.

5. The extent to which the world coal reserves do or do not gain competitive status will be significant, because the coal reserves, as has been noted, are so enormous.

6. Both the technology and the economics of extracting energy fuels from tar sands and shales will affect the development of conventional petroleum sources.

7. The success and timing of "new" sources of energy such as solar power, tides, and geothermal energy in the types on which the President asked for speeded up research in his June 4, 1971 announcement on a long-range energy program, may affect the projection but are difficult to access now. [105]

8. Further advances in the technology and engineering of economical, safe, transportation of energy fuels, including gas and oil, will be a factor especially significant in the Arctic.

9. It is not beyond the realm of possibility that the demands for pollution control and environmental protection will have a considerable bearing on the demands for oil. Changes in power-using vehicles and machinery may be made which throw emphasis to non-polluting or less pollutant forms of energy (solar, tidal, and geothermal energy have been mentioned as possible examples).

10. The effective demand for energy may also be affected by social, economic, or political maladjustments, such as economic depressions,

wars, blockades, etc., which might either increase or diminish demands for certain fuels in certain areas.

A 6.3.4 Some Tentative General Conclusions

The evaluation of the significance, from 1971 to the year 2000, of the arctic petroleum resources must begin with two estimates; one, the estimate of the actual reserves that exist in the Arctic as recoverable amounts; and, two, the trend of effective demands for arctic gas and oil, which in turn will be affected by several economic factors such as the competitive position of oil and gas, both in terms of comparative cost and comparative utility and on social acceptability. In this connection, it has been stated that "Of all the items that affect any development in the Arctic, and especially the development of natural resources in the regions, transportation is easily the most important.[106] At the moment that statement has merit; but by 1985 or 1990 there may be other factors that are equally or more critically important.

Whereas most of the above listed contingencies or variables may well warrant great caution in forecasting for the last two decades of the century, one may doubt whether the factors which now provide the impetus for exploration of arctic oil and gas will seriously reduce that impetus before 1980, and perhaps not even after that. Coal, as a competitor, has been losing ground to oil and gas. In 1970, 76 percent of U.S. energy came from oil and gas, as compared with 20 percent from coal. In the U.S.S.R. the trend has been similar in recent years. The President has now requested intensified development work on fast-breeder reactors, with the aim of completing a demon-

stration reactor by 1980. (apparently research on nuclear fusion was not emphasized). In a recent interview, Dr. John McKetta, Chairman of the National Energy Policy Committee, which had been commissioned and appointed by the Secretary of the Interior, predicted that fast breeder reactors would not produce a great increase in nuclear energy until after 1990. He suggested that 10 percent of nuclear-powered energy was a possible estimate for 1990.[107] Any substantial change in world energy sources prior to 1990 cannot now be predicted with any confidence.

The total problem of forecasting the oil situation was recently summarized by the Senior Editor of the Oil and Gas Journal as follows:[108]

" The 1970's promise to become one vast headache for U.S. industry and government planners in trying to forecast oil and gas needs.

"A rapidly changing life style in America, and the growing concern for the environment already are playing hob with old methods and tools of forecasting.

"Add to this an increasing inefficiency in the nation's use of energy and a tightening supply. That means trouble. ...... But at least one factor appears pretty certain: Oil will be the dominant supplier of a surge of U.S. energy demand in the decade."

If forecasting the energy picture for the 1970's is difficult, the problem of looking ahead to the 1980's and 1990's is far greater. Dr. Paul McCracken, Chairman of the President's Council of Economic Advisers has pointed out an additional worrisome fact about the energy situation - the fact that since 1966 the total energy consumptions has risen more rapidly

than real economic growth.[104]

3.4.3.3 Future North American Arctic Energy Development

A factor which has been largely responsible for the oil industry willingness to make a substantial investment in Alaskan North Slope oil development is, of course, the evident concentration of oil riches, with anticipated daily wellhead flow far greater than from most fields in the "lower 48". If other arctic Alaskan and Canadian reserves are equally promising, that fact will greatly spur development, even though transportation costs and production costs per well are comparatively high.

A significant factor in the U.S. - Canadian arctic oil development picture is the fact that, as indicated in the above summary, the arctic Alaskan reserves may be found to be far less than the Canadian, while the U.S. consumption rate now is more than 20 times greater, and may well continue to be. The U.S. interest in Canadian arctic petroleum is likely, therefore, to be strong. The U.S. market for Canadian oil and gas will probably be a major factor influencing the rate of Canadian development, although it may eventually prove to be economical for Canada to supply its East Canada market from its arctic oil, even if the current exploration between Greenland and Baffin Island prove to be unproductive. In any event, it seems clear now that Canadian arctic oil will be an important aspect of any U.S. - Canadian joint energy policy agreement, if such agreement is ever to be reached. Central to the North American energy

policy issue is, of course, the matter of imports from other Western Hemisphere sources and, more particularly, from the Eastern Hemisphere. The weighing of the forces which will affect import policy for the 80's and 90's is perhaps not possible now, but the economic, political, national security, and other arguments, have already surfaced to some extent. The content of the report of the 1970 "Oil Import Question" by the Cabinet Task Force on Oil Import Control, which emerged with divided counsel is perhaps indicative of the range and depth of views on the subject. The resolution of U.S. and Canadian interests may prove to be a long and painful process. However, unless there are breakthroughs in the field of new energy sources, the prospect would seem to be that a common policy on North American arctic oil development and distribution will be reached within the next 10 years. Meanwhile, environmental concerns are, of course, a delaying factor in the development of the oil reserves in Alaska and may also affect the developments in arctic Canada.

A.6.3.6 Future Development of Soviet Arctic Energy Resources

As has been noted above, present estimates are that more than 40 percent of the U.S.S.R.'s potential oil reserves are in the arctic or near-arctic regions. The estimates of arctic gas reserves in the U.S.S.R. are even more impressive, ranging up to 2 or 3 quadrillion cu ft, or perhaps five or six times the present proved U.S.S.R. reserves (4 427 trillion cu ft. In one respect the U.S.S.R.'s problems of arctic oil and gas development are simpler than the North American problem - the area is politically controlled

by one country alone. Another factor has been referred to also - that the main centers of U.S.S.R. consumer demand for petroleum products are in European Russia, which in turn could rather easily be connected by pipeline to the populous industrialized areas of Western Europe. Gas pipelines are already projected to West Germany, Italy, and eventually to Belgium. The continued explorations in the offshore North Sea areas may produce gas and/or oil deposits that would have the effect of slowing down the movement of Soviet gas and oil to Western Europe. Price (cost) factors, as well as political developments in the Middle East and Africa will also have significance for the timing and intensity of Western Europe demand for the U.S.S.R. oil and gas. The political factor is incalculable now but may well prove to be relatively minor.

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